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HUNTING SEASON STATISTICS AS AN INDEX TO RANGE CONDITIONS AND DEER POPULATION FLUCTUATIONS IN MINNESOTA [1]

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It has been stated at various times that Minnesota is fortunate in having had "any deer" hunting seasons. These statements have frequently contained the implication that with such seasons, Minnesota should have a minimum of deer problems. Unfortunately, this is not entirely true.

Certainly, "any deer" hunting seasons have prevented to a great degree such widespread range deterioration as has occurred in Michigan and Wisconsin. Yet, in Minnesota, deer are not now as plentiful as they were in the 1930's. Deer yard studies have indicated range deterioration and much heavier browsing in years past than at the present time. The probability exists also that natural plant succession in northern Minnesota cut-over areas may cause a decrease in the carrying capacity of the deer range. Balsam fir (*Abies balsamea*) particularly, is coming back strongly and replacing good deciduous deer browse species in the Superior and Chippewa National Forests.

To determine herd composition, fawn-adult percentages, and range conditions, a study was made of hunter kill data.

REPORT CARD KILL STATISTICS, 1942–1949

From 1942 through 1949, a total of approximately 250,000 deer was reported killed. These are not estimates but actual hunter reports. The reported take is broken down into 112,280 adult bucks, 81,200 adult does, 33,680 male fawns and 23,270 female fawns (Table 1).

In this study, it has been assumed the deer kill figures are representative of the composition of the Minnesota deer herd. This assumption seems quite probable at this time although there are possibilities for a degree of error. A few years ago, it may have been customary for hunters to "try for a buck" and this may be true of a small number of hunters today. However, present hunting season observations indicate any deer coming along is shot. Hunting parties divide the total take at the end of the season. It is known, of course, that sex and age identification is not always correctly reported, but it seems a large enough sample should cancel these yearly errors. No great degree of error should result

[1] A contribution from Pittman-Robertson Surveys and Investigations Project 11-R, Minnesota Division of Game and Fish.

TABLE 1.—MINNESOTA DEER STATISTICS—HUNTER REPORTS
1942–1949

Year	Hunter Kill Reports				Adult kill per cent	Fawn kill per cent	Fawn per Doe
	Bucks	Does	Fawn male	Fawn female			
1942.....	9,900	6,350	2,250	1,600	81	19	0.61
1943.....	7,900	5,850	2,600	1,800	76	24	0.75
1944.....	8,000	4,350	1,700	1,050	82	18	0.63
1945.....	20,500	15,650	6,300	4,800	77	23	0.71
1946.....	30,250	21,600	9,100	6,050	77	23	0.70
1947.....	15,400	11,650	5,100	3,400	76	24	0.73
1948.....	11,100	9,550	3,700	2,600	77	23	0.66
1949.....	9,230	6,200	2,930	1,970	76	24	0.79
TOTALS:	112,280	81,200	33,680	23,270			
AVERAGES:					77	23	0.70

from the adult-fawn classification. There should be little hunter prejudice in favor of bucks over does or fawns based on the entire hunting population, and there certainly should be no hunter discrimination for male over female fawns. In this respect, sex ratios are remarkably similar for both adults and fawns, and this similarity should counteract, to some extent, the idea a November season accounts for the surplus of bucks taken—although the rutting season may have some influence.

An eight years' average indicates the herd is made up of 77 per cent adults, and 23 per cent fawns. Males outnumbered the females 138 to 100 for adults and 144 to 100 for fawns. By percentage, this means 58 per cent males and 42 per cent females for adults; 59 per cent males and 41 per cent females for fawns. The fall fawn/doe figure is 0.70 (number of does divided into number of fawns or 81,200 divided into 56,950). If this 0.70 fawn/doe figure indicates fawn survival, it shows a great drop from the 1.5 figure so frequently quoted for fawn reproduction per doe. (In our calculations, no attempt has been made to assign a percentage figure to the number of yearling does bearing young.)

It has been customary to expect a poorer fawn crop following a severe winter or in areas where the range is in a "starvation" class. Suppose then, that a few examples are checked against this 0.70 figure.

ITASCA STATE PARK

In 1945, Itasca State Park, Clearwater County, was opened to hunting against strong public pressure. The basis for opening was heavy winter losses and badly deteriorated range condition with very little good browse reproduction. During the season, 2,048 deer were taken after which it was estimated that only 30 deer remained in the park. This estimate is thought to be quite accurate inasmuch as heavy hunting in 1946 resulted in a take of 119 deer and only 9 in 1947. On the basis of 2,078 deer (2,048 plus estimated 30 deer remaining), the pre-seasonal population was 41.6 animals per square mile. Severe winters and poor food conditions resulting from heavy overbrowsing had killed over 1,000 animals from the all-time high of 75 deer per square mile in 1935. Kill figures for

the 1945 Itasca Park take obtained at checking stations showed adults 79 per cent, fawns 21 per cent, does in excess of bucks by a 2 to 1 ratio, and a low per cent of fawns/doe. The sex ratio for fawns was 126 males to 100 females. Erickson (1949), in calculating the fawn/doe ratio, used only the "middle-aged" does, or 61 per cent of all adult does. These figures showed 575 does producing 396 fawns, or 0.7 fawns/doe. Actually, this figure is probably high as a percentage of both yearling and very old does will also have fawns. If all adult does are used, as was done in the calculations for the total reported state kill, then 944 does had 396 fawns, or 0.4 fawns/doe. This 0.4 fawn/doe figure taken from a known "starvation" area is considerably below the eight-year state average.

Table 2 shows kill data for Itasca and St. Croix State Parks for the 1945–1949 period. Although the sampling is small for the last four hunting seasons, it is interesting to note the gradual increase in fawn percentage take and the increasing fawn/doe ratio.

ST. CROIX PARK

St. Croix Park, Pine County, another trouble area, was also opened to hunting in 1945. Only 17 sections in the east side of the park were opened to unrestricted hunting, but 1,292 deer were taken, or a kill of 76 per square mile. Adult does outnumbered adult bucks by 508 to 270, or almost 2 to 1; male fawns outnumbered female fawns by 100 to 73. On the basis of 100, this would be approximately 137 males to 100 female fawns and again is similar to the state average. Adults constituted 81 per cent and fawns 19 per cent of the herd composition. The fawn/doe figure, based on 506 does and 173 fawns, was 0.34. Once more, this fawn/doe figure from another "starvation" area is considerably below the 0.7 eight-year state average.

In 1946, 14,760 acres in the west half of St. Croix Park were opened. The east half, which had been opened in 1945 was closed as was a refuge area of 3,680 acres in the center of the park. After a nine-day season, 1,392 deer, or 60 per square mile, had been taken. Sex ratios were 32 per cent males and 68 per cent females for adults; 43 per cent were males and 57 per cent females for fawns. The fawn/doe figure was approximately 0.51 (678 does and

TABLE 2.—DEER KILL DATA, ITASCA AND ST. CROIX PARKS, 1945–1949

Year	Deer Take	Per cent Adults	Per cent Fawns	Fawn/Doe	Adult Male-Female	Fawn Male-Female
Itasca State Park						
1945	2,048	79	21	0.4	100:200	126:100
1946	119	..	..	....	138:100	.....
1947	9	..	..	....	.....	.....
1948	40	77	23	0.75	150:100	(6 animals)
1949	119	76	24	0.85	177:100	120:100 (only 11 animals)
St. Croix State Park						
1945	1,292	81	19	0.34	100:188	137:100
1946	1,392	74	26	0.51	100:215	100:130
1947	207	70	30	0.74	100:144	(more males)
1948	137	70	30	0.76	100:128	141:100
1949	255	65	35	1.15	116:100	100:114

344 fawns).

In 1947, the entire park, with the exception of a 4 1/3 square-mile refuge area, was opened to hunting on the fifth day of a nine-day season. Only 400 permit hunters were allowed to hunt based on park deer censuses. During the five-day season, 207 deer were taken. Sex ratios were 41 per cent males and 59 per cent females for adults; 57 per cent males and 43 per cent females for fawns. The fawn/doe figure was approximately 0.74 (85 does and 63 fawns).

In 1948, the same area was opened as in 1947, and 400 permits were issued. The season, however, was for nine rather than five days. One hundred and thirty-seven deer were taken with fawns making up 30 per cent of the take. The fawn/doe figure was 0.76.

In 1949, for the third consecutive season, all of St. Croix Park, with the exception of the same area closed in 1947 and 1948, was opened to deer hunting. Permits were not issued and the number of hunters in the park was not controlled. State personnel checked 255 deer, and for the first time since the opening in 1945 sex ratios were higher on the male side. The fawn/doe figure was 1.15 (76 does and 88 fawns). Just as in the case of Itasca Park, fawn percentage take and fawns/doe showed a gradual increase during the 1945–1949 period (Table 2). In general, the adult sex ratios for both areas also showed a change from a preponderance of does to an excess of males similar to the state ratios.

MUD LAKE NATIONAL WILDLIFE REFUGE

The Mud Lake National Wildlife Refuge in northwestern Minnesota, first opened to hunting in 1949, tells a different story. This area constitutes a special problem and many answers are yet needed. Its gross area is about 60,000 acres, but relatively little is deer range. It seems evident that a special project should be set up to determine the palatability of a number of willows and aquatics used as browse in this area. Calculated live weights for animals taken during the 1949 season were as follows: 107 bucks (including spike bucks) showed a maximum of 331 pounds, a minimum of 128, and an average of 236 pounds; 127 does showed a maximum of 211 pounds, a minimum of 131, and an average of 167 pounds.

Yet, despite the large size and healthy appearance of Mud Lake deer, an estimated 210 animals died in the spring of 1950. Although the primary reason for the mortality was difficult to ascertain, deep snow in April and early May, high waters resulting in a limited area available to deer, a diminished food supply in these restricted areas, overexertion and drowning have been advanced as causative agents (Hunt, 1950).

The 1949 kill was made up of 107 bucks, 131 does, 83 male and 100 female fawns. Adults made up 56.5 per cent and fawns 43.5 per cent of the kill; the adult sex ratio was 100 males to 123 females and 100 males to 120 females for fawns. The fawn/doe figure was 1.4. Note the 43.5 per cent fawn kill, the excess of does over bucks, and the 1.4 fawn/doe figure.

The rapid expansion of the Mud Lake deer herd is relatively new and apparently is similar, prior to the 1949 season, to the early Itasca and St.

Croix herds and is probably increasing rapidly at the expense of browse conditions. It cannot be stated definitely at this time that the herd is beyond carrying capacity although there are indications that it has reached this point (Krefting and Lee, 1949). More knowledge is needed of the quality of browse in this area.

HILL FARM DEER HERD

Deer damage reports have been received frequently by the Minnesota Division of Game and Fish from the 5,000 acre Hill Farm located just north of the St. Paul city limits. Damage was so extensive in 1949 that the owner asked the Division to control the herd. Accordingly, 29 deer were taken on February 6, 1950 (Erickson, 1950). The following day an aerial survey was made and 72 deer were counted.

A sample of 29 deer is admittedly small but some interesting information was obtained. Nineteen animals were females, 10 were males. Eleven of 13 adult does, 84.6 per cent, bore twins; two carried single young. Two of the six fawn does were pregnant and carried single young.

GEGOKA COOPERATIVE WILDLIFE UNIT

Stenlund *et al* (1952) summarized deer kill data for the Gegoka area in northeastern Minnesota for 1942–1949. This summary showed a kill of 1,334 deer, of which 20.8 per cent was fawns. The male-female ratio (including fawns) was 130 to 100 although female fawns were in excess of males; 456 does were taken and 277 fawns, or 0.61 fawns/doe. It is Stenlund's belief that the northeastern Minnesota deer range is deteriorating faster than the remainder of the state and he points out that the 0.61 fawn/doe figure may be an indicator in that it is lower than the 0.70 state average for the same period. In addition, however, he believes that predation may be more of a factor in the northeast.

CLOQUET VALLEY STATE FOREST

Some statistical information is available from the Cloquet Valley State Forest for the late 1930's.

Morse (1937) wrote, "The recent deer hunting check yielded figures that seem to indicate a decrease in population from last year. Hunting pressure registered a definite increase over last year, while the success ratio showed a decrease from 0.5 to 0.25. Reports from hunters, for the most part, reflected a scarcity of deer. Our deer check results, then point to a reduced deer population, and this trend has been borne out by our census drives the past three years in which there were 20, 15, and 10 deer, respectively, counted per section of area."

An intensive mortality study in a 282-acre white cedar yard was made in April and May, 1937. Nine carcasses were found, or a total of 21 deer per section of yarding area (Morse and Burcalow, 1941).

In 1938. six deer checking stations tallied 1,077 deer during the hunting season. These checking stations controlled a calculated 274 square miles of the 349 square miles of huntable area in the forest. Kill data were as follows: 411 adult bucks, 469 adult does, 129 male and 68 female fawns. Fawns made up 18.3 per cent of the kill (Burcalow and Christopherson,

1938). The fawn/doe figure was 0.42 (469 does and 197 fawns).

Age determination of 524 male deer based on antler beam measurements showed the following:

Age Class	*Number of Deer*	*Per cent of Total*
1½	289	55.2
2½	47	8.9
3½–4½	114	21.8
5½ and older	74	14.1
	524	100.0

The small percentage of 2½ year old deer (8.9) may well reflect the severity of the 1936–37 winter.

DEER KILL STATISTICS, 1919–1941

Primarily, this paper has been concerned with the 1942–1949 period. Analysis of the 1919–1941 data is difficult. There were a number of closed seasons, a year when no breakdown was made for the reported kill (1930), a year when fawns were protected (1936), and years when the fawn take was not differentiated by sex. A graph (Figure 1) of Minnesota deer hunting statistics, 1918–1949, has been included.

During the 23 years there were 8 closed seasons. The average adult kill was 81.6 per cent and the fawn kill 18.3 per cent. The fawn/doe figure averaged 0.71. Throughout the entire period males outnumbered females for both adult and fawn classifications and by a greater margin than in 1942–1949.

Hunter preference for bucks in the early years should not account for the excess of adult males over adult does when it is noted that male fawns were also greatly in excess. Were males actually so much in excess twenty to thirty years ago during the low population period, or does an increasing population and a larger take tend toward showing a greater equality of sexes? Fawn sex ratios show a relatively uniform decline toward the 1942–1949 erratic, increasing and decreasing, and arratic, increasing and decreasing, and finally approaching the 1942–1949 average from 1937 on. Coincidentally, it has been noted in the Itasca and St. Croix Park data that a population greatly reduced by heavy hunting may tend toward an excess of males.

Four successive hunting seasons (1919–1922) showed a gradual yearly decrease in the reported kill, and at the same time showed a gradual increase in the adult kill percentage (Table 3). During this time the fawn/doe figure averaged 0.81. If the data can be relied upon, it may be assumed that the deer population was relatively low and affected by successive hunting seasons. From 1922 through 1931, with closed seasons in 1923, 1925, 1927, 1929, and 1931, the reported kill increased. The adult kill average per cent for 1924, 1926, and 1928 increased to over 82 per cent and the fawn/doe figure decreased to 0.69 [Table 3]. Three successive seasons (1932–1934) showed smaller yearly reported kills than in 1928 and 1930 while the fawn/doe figure continued to go down and reached its lowest point in 1937 (0.50).

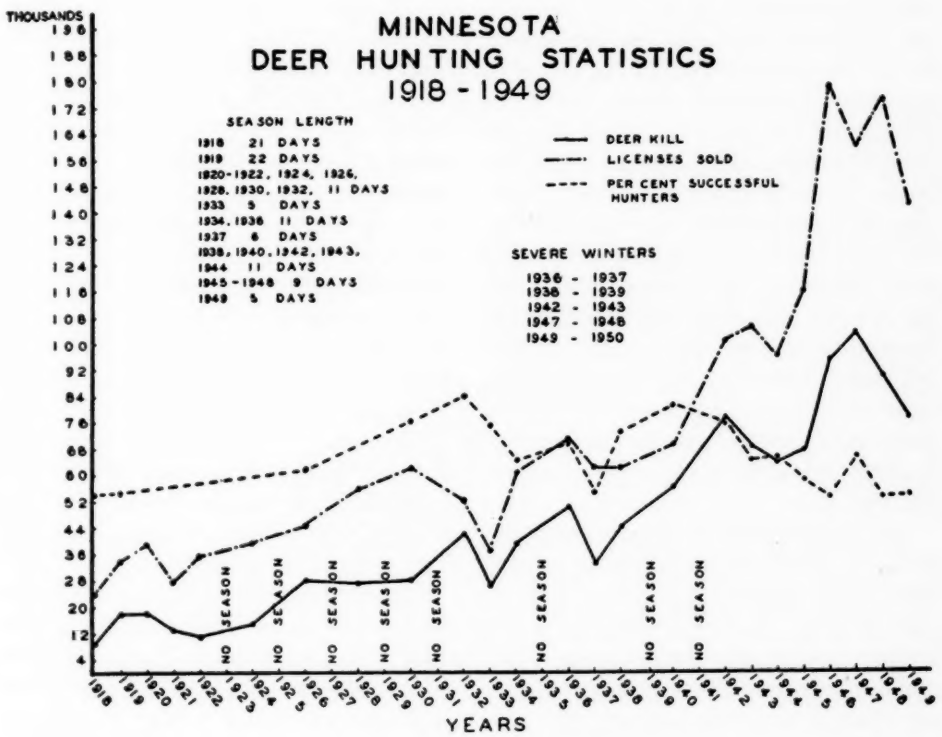
Again, and perhaps not so strangely, the reported take was less in 1937 than in 1936. The winters of 1936–37 and 1938–39 were extremely hard on deer and thousands were lost. In this connection, the 1937 figures (81 per cent adults, 19 per cent fawns, and 0.50 fawns/doe) have interest. The fawn/doe figure had decreased from 0.55 in 1934 to 0.50 in 1937 even though there had

TABLE 3.—MINNESOTA DEER STATISTICS—HUNTER REPORTS
1919–1941 *

Year	Hunter Kill Reports				Adult Kill per cent	Fawn Kill per cent	Fawn per Doe
	Bucks	Does	Fawn Male	Fawn Female			
1919.....	8,900	5,200	2,750	1,450	77	23	0.81
1920.....	9,600	5,050	2,500	1,400	78	22	0.77
1921.....	7,300	3,400	1,800	1,050	79	21	0.84
1922.....	6,350	2,700	1,450	750	80	20	0.80
1924.....	9,500	3,300	1,550	850	84	16	0.73
1926.....	11,500	7,400	2,950	1,850	80	20	0.65
1928.....	16,400	6,350	2,800	1,750	83	17	0.71
1930.....	No breakdown of reported kill.						
1932.....	11,450	5,900	(4,200)	....	80	20	0.71
1933.....	5,500	3,650	(2,500)	....	78	22	0.68
1934.....	9,750	4,600	(2,550)	....	84	16	0.54
1936.....	11,350	6,500	Fawns protected		(?)	(?)	(?)
1937.....	5,600	4,450	(2,250)	....	81	19	0.50
1938.....	7,050	5,400	2,100	1,650	77	23	0.69
1940.....	9,700	6,200	2,700	2,100	77	23	0.77
TOTALS:	129,950	70,100	20,600	12,850			

Fawn figures shown in parenthesis are not differentiated by sex and have not been included in the totals.

* Closed seasons in 1923, 1925, 1927, 1929, 1931, 1935, 1939, and 1941.



not been a season in 1935 and fawns were protected in 1936.

From 1937 to the present, the fawn/doe figure has varied between 0.60 and 0.79 with the adult kill varying from 75 to 82 per cent. This situation seems to be consistent with the opinion of Minnesota biologists that the deer herd has been reduced from the "high" in the 1930's and in more recent years has maintained a rather uniform population but increasing or decreasing with the severity of the winters and gain or loss in browse conditions.

Miscellaneous Winter Loss Data. A survey of data obtained on State Forests from hunting season checks (male deer) gives strong support to "wintering conditions" as a deer mortality factor. Fawn deer, surviving the 1936–37 winter, appeared as 1½ year old males in the 1937 hunting season. This class comprised 15.7 per cent of the total male deer checked. This is in contrast to 21.4 per cent in 1938 and 22.3 per cent in 1940 for the same class. In 1938, and now in the 2½ year class, they comprised only 11.1 per cent. The 1937 2½ year class comprised 14.9 per cent, and in 1936 and 1940 as much as 19.6 per cent. It is apparent that the heavy loss of fawn deer during 1936–37 is clearly reflected for the three following hunting seasons in terms of reduced proportions of the male age class representing the deer born in the summer of 1936.

It is also significant to note that the greatest continuous reduction in the deer herd during the years 1935–40 occurred in the area supporting the highest population density, namely the Superior National Forest. From a high of 19.9 deer per section in 1935, the herd dropped steadily to a low of 12.2 deer per section in 1939 (Morse and Burcalow, 1941).

Analysis and Conclusions. It has been assumed that the reported kill figures for 1942–1949 are representative of the Minnesota deer herd composition. Adult-fawn and male-female ratios were quite consistent during this period and averaged 77 per cent adults and 23 per cent fawns. Males outnumbered females in both adult and fawn classifications in approximately the same ratio. The eight-year fall fawn/doe figure was 0.70.

In two areas known to have severely overbrowsed range, Itasca and St. Croix State Parks, the fawn take was below the state average. Results from the first opening seasons in these two areas showed the fawn/doe figures to be 0.4 and 0.34, respectively. Adult does outnumbered adult bucks by almost 2 to 1 in both areas; the male-female fawn ratio was 126 to 100 for Itasca and 137 to 100 for St. Croix. After five successive seasons, the sex ratios more nearly approximated the state averages and the fawn/doe figures had increased to 0.85 in Itasca and to 1.15 in St. Croix in 1949.

In northeastern Minnesota, where it is believed the range is deteriorating more rapidly than elsewhere in the state, the fawn take and the fawn/doe figure of 0.61 were below the 0.70 state average during the same period. In 1938, hunting season checks in the Cloquet Valley State Forest showed a fawn/doe figure of 0.42.

The Mud Lake National Wildlife Refuge, with a rapidly increasing deer population, showed an excess of does over bucks by 123 to 100, a fawn take of 44 per cent, and a fawn/doe figure

of 1.4. The fawn take and the fawn/doe figure greatly exceeded the state average.

On the Hill Farm, which is another relatively new deer concentration area, adult does exceeded adult bucks almost 2 to 1. Eleven of 13 adult does bore twins; two carried single young. This is approximately 1.85 foetuses/doe. Two of the six fawn does were pregnant and carried single young. The sample, however, is too small to be significant. It must be noted also that this area is not subjected to the severe weather found farther north.

A state average of 0.70 fawns/doe taken during eight hunting seasons seems very low when compared with the 1.5 figure quoted for fawn reproduction per doe. In 1950, 39 does found dead were checked and found to have 69 foetuses, or an average of 1.77 per doe. Most of these were found in northern Minnesota but compare favorably with the Hill Farm statistics. Although the sample is small, it makes the fall fawn/doe state average figure of 0.70 seem very low. Yet, figures taken from "starvation" range areas seem to indicate such a condition exists. If this 0.70 figure is a good approximation, mortality must occur to the foetus, to the newly born fawn, to fawns caught in unseasonable spring weather, or from poor range directly affecting the reproductive potential of female deer. From early summer to late fall, predation and accident mortality should not be too important. It seems, therefore, that the bulk of the mortality must result directly and indirectly from range conditions and severity of winters and affecting pregnant does in such a way that a large percentage of foetuses never become live and healthy fawns.

Hunting season results for 1949 from Itasca and St. Croix Parks are interesting in that they show a return to normal sex ratios and a gradual increase in the fawn/doe figures over those found after the initial 1945 opening.

In regard to winter effects, interesting results are obtained when comparing the eight-year state average figures with specific hunting seasons. For a comparison, two seasons have been chosen—1937, the season following the hard winter of 1936–37, and 1946, the year of Minnesota's highest hunting season take. Nineteen hundred forty-six was also a good fawn year. In 1937, approximately 12,300 deer were reported shot: 5,600 bucks, 4,450 does, and 2,250 fawns. Adults made up 82 per cent and fawns 18 per cent of the total. The fawn/doe ratio was 0.50. In 1946, 66,930 deer were reported: 30,240 bucks, 21,580 does, and 15,110 fawns. Adults made up 77 per cent and fawns 23 per cent of the total. The fawn/doe figure was 0.7. If a theoretical deer population of 300,000 adult animals were set up and the eight-year average used as a basis for computing the herd composition, 126,000 animals would be adult does (43 per cent of adults were does). If the fawn/doe ratios for 1937 and 1946, 0.5 and 0.7 respectively, were applied to the 126,000 adult does, there would be 63,000 fawns in 1937 ($0.5 \times 126{,}000$) and 88,200 fawns in 1946 ($0.7 \times 126{,}000$). Thus, a severe winter and poor browse conditions might cut the huntable deer population by 25,200 animals (88,200 minus 63,000) even though the breeding populations were numerically equal.

Miscellaneous winter loss data from State Forests give strong support to the

effects of wintering conditions as indicated by the correlation between bad winters and the corresponding percentage take in the age class of that year.

It is difficult to generalize for the 1919–1941 statistics and the accuracy is doubted, particularly the earlier years. No explanation can be given to account for the preponderance of males unless a larger take tends toward showing a greater equality of sexes, or that a male excess is normally found during the "low" in population. Actually, perhaps the most valuable point observed in this period is that the 1937 reported kill was less than the reported 1936 take and that the fawn/doe figure decreased from 0.55 in 1934 to 0.50 in 1937 even though there had not been a season in 1935 and fawns were protected in 1936.

SUMMARY

1. In areas which have been protected from hunting for a long time and where the deer population has increased beyond the sustained carrying capacity and resulting in known starvation losses, (a) adult does are greatly in excess of adult bucks, (b) the fawn percentage of the population and (c) the fawns/doe are considerably below the state average.

2. Heavy hunting in areas such as described in (1) above, may result in increasing the browse supply, in bringing about a balanced sex ratio, and in increasing the fawn/doe survival.

3. In rapidly increasing deer population areas which have not reached, or are just reaching carrying capacity, such as the Mud Lake area, (a) adult does are in excess of bucks, (b) the fawn percentage of the population, and (c) the fawn/doe figure will be above the state average.

4. Males are in excess of females in both fawn and adult classes normally throughout the state.

5. Based on a small sampling, potential fawn reproduction (foetuses per doe) seems to be quite high in Minnesota and may be over 1.5. However, fawn survival (fall fawn/doe figures) is low, not more than 0.7 for an eight-year average. Sample areas, notably Itasca and St. Croix Parks, indicate that such a condition is entirely possible. The Itasca figures have special merit in that a very large percentage of the entire herd was taken in one hunting season and should reflect quite accurately the herd composition of that area.

6. A small variation in the fall fawn/doe figure (survival percentage) will greatly affect the huntable population from year to year.

7. The bulk of the mortality must result directly and indirectly from range conditions and severity of winter and spring months and affecting pregnant does in such a way that a large percentage of foetuses never become live and healthy fawns.

8. If the assumption is correct that these reported kill figures indicate the approximate composition of the Minnesota deer herd, it then appears that accurate kill data of adult-fawn take percentages and fawn/doe figures plus age-class determinations may be used as indicators of population fluctuations and range conditions.

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WEIGHT CHANGES IN FISH AFTER DEATH

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INTRODUCTION

The killing of entire fish populations with rotenone is now a technique widely used in both fisheries research and management. Data obtained from a careful inventory of the dead fish may be used to estimate carrying capacity, to evaluate applied management methods, to interpret interspecific competition among the fishes, and to obtain a basis for restocking the treated lake. The procurement of quantitative data on a poisoned fish population necessitates that fish be gathered over a period of several days because many of them sink to the bottom and cannot be collected until gases within the body lift them to the surface. The weight of these dead fish will have changed considerably from that of others that may have been collected soon after rotenone was applied. If one objective of such a census is to gather information on the total weight of fish supported by a body of water, the use of some factor is necessary to convert weights of partially decomposed fish to weights of fresh fish. No matter how carefully the fish are collected and recorded, the total weight calculation is no more accurate than is the factor that is used for correcting the weight changes which follow death.

In the experiments described below, freshly killed fish were allowed to decompose under controlled temperature levels, and the weight changes were recorded.

METHODS

The changes in body weight of fishes were measured in a series of laboratory tests involving twenty-five groups of ten fish each. The water temperatures in several indoor aquaria (20 gallons capacity) were maintained at selected levels by means of electric thermostats. These temperatures ranged from 17 to 42 degrees C. Thermal stratification of the water was prevented by fine streams

TABLE 1.—WEIGHT CHANGES OF BLUEGILLS AND YELLOW BULLHEADS, EXPRESSED AS PER CENTS OF FRESHLY KILLED FISH, THAT OCCURRED DURING DECOMPOSITION UNDER CONTROLLED TEMPERATURES

Temperature °C.	Temperature °F.	Weight of ten fish (pounds)	Hours After Death: 4	8	12	16	24	32	40	48	56
Bluegills											
42	107	1.25	+2.55	−2.13	−7.34	−11.64					
40	104	1.23	+4.83	+1.54	−5.03	− 9.68					
38	100	0.95	+3.89	+1.69	−4.82	− 8.59	−16.91				
36	97	1.17	+3.38	+1.40	−4.53	− 8.27	−18.95				
34	93	1.34	+3.10	+2.53	+0.03	− 4.38	−11.39				
33	91	1.07	+7.48	+5.61	+0.93	− 5.61	−13.08	−15.89	−19.63	−22.43	
32	90	1.49	.....	+2.22	.....	− 3.75	−10.90	−19.57	−26.88		
31	88	0.90	+6.67	+6.67	+3.33	− 2.22	− 7.78	− 8.89	−13.33	−15.56	−20.00
30	86	1.13	+2.70	+3.13	+2.13	+ 0.74	− 4.11	−13.26			
29	84	0.99	+6.06	+5.56	+5.05	0.00	− 7.07	−12.12	−14.14	−20.20	−20.20
28	82	1.21	+3.42	+3.71	+3.49	+ 2.34	− 2.45	− 6.82	− 8.22		
27	81	1.01	+6.47	*+4.48	*+3.48	+ 2.49	− 6.47	−10.45	−13.43	−17.41	−20.40
26	79	†1.60	+2.56	+3.91	+4.09	+ 4.07	− 0.48	− 5.66	− 7.71	−11.59	
26	79	‡1.05	+2.56	+3.44	+3.51	+ 3.52	− 0.42	− 4.45	− 6.47	−10.52	
25	77	2.44	.....	+6.30	.....	+ 6.20	+ 0.20	− 6.20	−10.40	−12.50	−13.60
23	73	§1.01	+3.96	+4.95	+6.44	+ 6.93	+ 7.92	+ 6.93	+ 2.97	0.00	0.00
21	70	2.63	.....	+3.50	.....	+ 4.00	+ 3.80	+ 2.50	− 1.80	− 6.30	− 8.60
19	66	2.55	.....	+4.30	.....	+ 6.40	+ 6.50	+ 6.50	+ 6.60	+ 3.60	− 1.10
17	63	2.33	.....	+3.86	.....	+ 5.92	+ 6.09	+ 8.15	+ 8.28	+ 7.30	+ 5.75
Yellow Bullheads											
42	107	3.99	.....	+1.70	.....	− 1.16	− 7.70	−19.90			
38	100	§4.37	.....	+1.90	.....	−13.70	−19.20	−28.80			
30	86	3.99	.....	+6.46	.....	+ 8.50	+ 7.90	+ 6.90	− 3.80	− 9.50	

* Fish exposed to air for 30 minutes
‡ Fed before experiment
† Starved before experiment
§ Exceptional group—see text

of air bubbled in from the bottom. After 24 hours, water temperatures in the aquaria remained fairly constant, except that the thermostats allowed a variation within one degree centigrade. Room temperature was constant during the tests.

Bluegills, *Lepomis macrochirus*, and yellow bullheads, *Ameiurus natalis*, were brought alive into the laboratory and held for at least one day, so that food in the digestive tract would not influence the rate of tissue decomposition. Ten specimens of nearly equal size were selected for use at each temperature level. Individuals of each group of ten fish were killed by pithing, then measured, weighed and placed immediately in wire baskets suspended in an aquarium. First, at 4-hour intervals, and later at 8-hour intervals, the fish were removed, allowed to drain for one minute and weighed. In the first experiments, weights of individual fish were taken; in later tests the fish were weighed by groups to reduce the time they were removed from water. Except for the two methods of weighing, the same procedure was followed in all tests.

Twenty-two groups of bluegills were used in this experiment, each group being allowed to decompose in water of a controlled temperature within the range of 17 to 42 degrees C. For a comparison of the decomposition rates three experiments using yellow bullheads were run at three temperature levels within the same range. All results are recorded in Table 1 except for those of three groups of bluegills which were duplicates of previous tests run at 32, 38, and 40 degrees C. In water below 26

degrees C., fish remained intact for several days; in order to reduce the table of data, the final weights were not given for these low temperatures but are shown graphically in Fig. 1. To determine the influence of food in the stomach on the rate of decay, two groups of bluegills were tested at 26 degrees C.; one having been fed well just before the experiment and the other starved for three days.

RESULTS

Weight changes followed a similar pattern of gains and losses for all temperatures tested (Fig. 1). The fish gained weight immediately after death due to the absorption of water through the skin. When decomposition began, loss of weight occurred at a fairly regular rate until the body was completely destroyed. At temperatures above 30 degrees C., the initial gain and subsequent loss of weight was very rapid. The gain in weight would not be detected at high temperatures unless test weighings were made within the first 24 hours. In contrast, at temperatures below 22 degrees C., the fish may actually gain weight for seven or eight days after death. The rate of weight loss is more irregular during advanced decomposition, particularly at low temperatures where the soft, slowly decaying tissues remain intact for a long time.

When the dead fish were gaining weight, little skin color had been lost, very little mucous covered the body

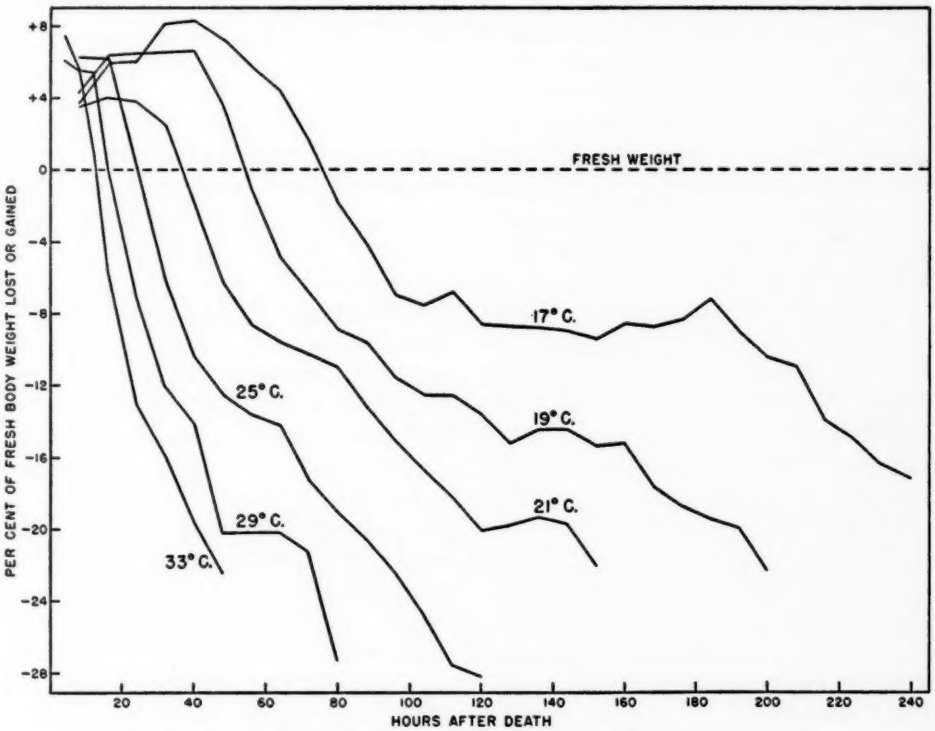

FIG. 1. Change in weight of bluegills after death at different temperatures.

surface, and the fish did not float. As the weight of the fish reached the peak of its gain, heavy slime covered the body. This slime persisted as the weight began to decline, at the same time the skin color faded and the body became stiff. As the weight dropped again to the level of the freshly killed fish, decomposition was well under way and many changes in appearance occurred. The heavy slime and skin color disappeared, the tissues were swollen, the body became limp, and the eyes began to bulge. Between losses of 1 to 5 per cent of the weight, the eyes were actually pushed outward from their sockets by gas formation within the body. The anus ruptured and the body tissues became quite soft and distended by internal gases. When weight losses approached 11 to 14 per cent, foul smelling gases were liberated from the body cavities. After the weight loss had reached 19 to 22 per cent, less gas was liberated, pieces of skin were sloughed off, the tissues collapsed and became very soggy. The body soon fell apart, usually with the opercular and jaw bones being the first parts to drop off.

The smooth-skinned bullheads showed a pattern of weight changes dissimilar to those of the sunfish (Table 1). The groups of bullheads held in water at 42 and 30 degrees C. revealed much slower changes in weight than were found for bluegills at similar temperatures. This difference could have been due only partly to the difference in average size of the individuals of the two species. The third group of bullheads (held at 38 degrees C.) lost weight rapidly, showing weight changes somewhat different from those of the other groups and indicating the need for additional tests on this species.

Exposure of decomposing fish to air will influence their rate of weight changes. The bluegills tested at 27 degrees C. (Table 1) were removed from the water for 30 minutes, 7 hours after death. Unlike the groups of fish at slightly higher and lower temperatures, the weight of these fish dropped off rapidly between the 4- and 8-hour weighing periods. As decomposition progressed, this group continued to lose weight more rapidly than was to be expected.

The group of bluegills held at 23 degrees C. (Table 1) illustrates that this usual sequence of weight changes may not always occur. These fish gained weight continuously for 24 hours, and did not drop below the fresh weight for 72 hours.

DISCUSSION OF RESULTS

There are three primary causes for weight changes in dead flesh: autolysis, bacterial action, and diffusion of liquids through the integument. The first, autolysis, is the disintegration of body tissues due to the digestive action of their own enzymes. Although this process is not responsible for rapid changes in weight, it begins immediately after death and continues until the tissues are destroyed. The second, bacterial action, is associated with autolysis, but causes more rapid changes, usually with subsequent production of gases and enormous distention of the body. Although the bacteria have not been identified, different kinds seem to take part in this process. Those that are effective during the first stages of decay

are supplanted by others which continue the tissue destruction. During the change of bacteria, there may be a momentary interruption in decomposition, so that the rate of this process is not uniform. The irregularities in weight changes are most evident during advanced decomposition and particularly at low temperatures which produce relatively slow rates of disintegration. Such a sequence of bacterial changes is typical of many well-known processes of fermentation and decay.

The third and very important process involved in weight changes is the passing of fluids through the skin. Immediately after death of the fish, the permeability of the skin is altered and the fish begins to gain weight due to the entrance of water into the body tissues. As autolytic and bacterial actions liquefy internal tissues, fluids leave the body through its permeable covering. In advanced stages of decomposition, weight is lost when the anus ruptures and scales and pieces of skin slough off. Such losses are unimportant in comparison with those due to the three primary processes mentioned above.

These processes of decomposition are influenced by many factors and consequently make the determination of the causes of the weight changes difficult. The most important factors affecting decomposition are temperature, which influences the rate of destructive processes, and time, which determines the total effect under the existing conditions. If a population is killed by poisoning, one can determine, within practical limits, the time that has elapsed before the fish are weighed. On the other hand, it is possible to know only roughly the temperatures to which each fish has been exposed. For example, fish on the cold bottom of a pond will lose less weight in 72 hours than others in the warm surface water will lose in 16 hours. This emphasizes the importance of gathering fish as soon as they rise to the surface.

Also, as shown above, exposure of the dead fish to air alters the rate of weight changes. The permeability of the skin may be temporarily affected, and there will be loss of weight due to drying of surface tissues. Bloated fish floating in warm shoal waters are exposed to air and flies above and moist, bacteria-promoting conditions below. Chemical conditions of the water likewise might modify the rate of decomposition by influencing the diffusion of fluids and the growth of bacteria. The size of individual fish is still another factor—the smaller the fish, the greater the ratio of surface area to volume of flesh and thus the more rapid exchange of body fluids through the skin. The rate of weight losses is increased by rupture of the body cavity, disturbance by wind action, injury by turtles and other animals, and handling when collected.

Food in the stomach may affect the rate of weight change (Table 1). Since the changes measured in these tests are based on per cent of total body weight, the actual weight of food in the stomach may account for certain differences between fish fed and fish starved before death.

Various species of fishes show different rates of weight changes as was illustrated by the differences between bluegills and bullheads in these experiments.

Krumholz (Journ. Wildl. Mgt. 14(4): 413–424, 1950) found that changes in weight were different for green sunfish (*Lepomis cyanellus*) and largemouth bass (*Micropterus salmoides*) picked up from the same pond on the same days. The green sunfish lost 9.3 per cent of their body weight between the first and second days and 18.8 per cent by the third day; whereas, the bass actually gained 6.0 per cent the first day, remained at that weight a day and by the fourth day had lost only 1.8 per cent of their body weight. Even though Krumholz does not account for these striking differences and gives no records of water temperatures, it seems probable that temperature was an important factor. Green sunfish are more closely associated with the shallow waters of ponds than are the bass, so that when the poison was applied the sunfish may have died in warm, shallow water while the bass sank to the bottom in deeper water and were exposed to lower temperatures. Fish associated with shallow water are usually affected by poisons before those that seek deep water. This suggests that the green sunfish may actually have been dead longer than the bass although this time interval would not account for the differences in the rate of weight changes between the two species. Even though relative sizes of the two species would be expected to influence the rate of weight changes, these differences in rate of weight changes cited by Krumholz appear to be attributable indirectly to the difference in habits of the two fishes.

WAYS OF ESTIMATING CHANGES IN WEIGHT

When this investigation of weight changes was begun, it was assumed that a correction factor might be determined to express the relationship between time, temperature, and change of body weight. Temperature-hours were calculated, which in this instance meant adding the degree-hours of temperature between eight-hour weighing periods. In other words, at 20 degrees C. the cumulative temperature-hours would be 480 in 24 hours. This proved to be a logical approach but revealed that there was no constant relationship between temperature-hours and weight change. At first inspection the slope of the plotted lines expressing weight losses appeared to be similar for each temperature. However, the slope was actually much steeper for higher temperatures than for lower ones, indicating that a simple mathematical expression would not apply to the different lines. It is possible that an exponent of either time or temperature would express a given level of decomposition (per cent of body weight). But, since the same exponent would not represent the level of decomposition for different times and temperatures, there is little practical value to this idea.

Three methods for correcting changes in weight have some possible practical use: (1) An approximate correction for weight could be calculated from a sequence of weight changes which follows a known time-temperature sequence, such as is expressed in Fig. 1. The calculation would involve a determination of the average temperature of the water in which the fish were decomposing. This method could be used only if one knew, from previous experiments, the rate of weight changes which were characteristic of each of the species in-

solved, when exposed to various water temperatures. (2) The weight could be corrected by identifying the stage of decomposition of a fish and associating that stage with a specific percentage of weight gain or loss. As in (1) this method requires previous testing, to correlate the external appearance of a dead fish with per cents of weight gain or loss; such tests would have to be made for the more common species likely to be found in poisoning operations. Though rough, this method would certainly be more accurate than assuming, as some biologist may do, that by the second or third day after poisoning the fish have lost a certain per cent of weight. My observations indicate it is possible to estimate within about four per cent the actual weight change. Since this method does not require measurements of temperature, nor even time, it would be useful in situations where more accurate work was impossible.

(3) By far the best procedure is to obtain average weights for various species of fishes of selected length ranges at the time they are poisoned. Later, as decomposition progresses, weights of the same species of fishes of the same length ranges can be adjusted upward to conform to the average weights of the fresh fish. In other words, if freshly killed bass in the 9.8 to 10.2-inch size group averaged 0.50 pounds and fish of the same size averaged 0.47 pounds at the second collection, one would need to correct for a six per cent loss in the partly decomposed fish. Krumholz (*op. cit.*) used this general method on Indiana ponds. It is actually unnecessary to weigh additional dead fish after adequate samples of fresh dead fish have been weighed unless the per cent of weight loss is of particular interest. The fresh weight of the decomposing fish could be determined simply by sorting them into size groups, counting them, and calculating their fresh weight from the perviously measured length-weight relationship. Whatever the method employed, the increased accuracy would undeniably justify the extra work.

Any method of determining weight changes involves much extra work; no simple calculation can be applied to fish killed for population studies made under widely different natural conditions and the biologist may have to devise a suitable method for each situation. The purpose of the experiments reported here has been, not so much to answer the question of how to correct the weights of dead fish, as to emphasize the importance of changes in weight of decomposing fish in critical population studies.

Summary

1. The changes of weight in fishes following death are relatively large, and should be considered in quantitative population studies.

2. During a short period after death, fish show a gain in weight which is followed by a more or less continuous decline until the body disintegrates.

3. Certain physical characteristics are associated with stages of decomposition, which in turn are related to certain per cents of weight lost.

4. Weight changes are caused by three primary processes: autolytic and bacterial action within the body and a diffusion of fluids through the integument.

5. The speed of these processes is mainly governed by time and tempera-

ture, although their rates may vary somewhat in different sizes and species of fishes, or be influenced by food in the digestive tract, by the chemistry of the water, by exposure to drying, and by mechanical disturbance of the decomposing tissues.

6. Adjustment of the weight of decomposing fish can be made to give fresh weight (1) by estimating the average temperature to which the fish have been exposed for a known period of time and, from previously determined time-temperature-weight loss relationships, determining the required correction; (2) by relating the physical appearance of the decomposing fish to a corresponding per cent of weight change; or (3) by determining the average weights for various species of fishes of selected length ranges at the time they are poisoned and applying this average weight to fishes of the same species and sizes that are collected at later periods.

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MUSKRAT MOVEMENTS AND POPULATION DYNAMICS IN MISSOURI FARM PONDS AND STREAMS

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Management of muskrats in a state with many farm ponds must attempt to reconcile two groups: the commercial trapper who desires to increase the population, and the farmer who usually desires to eliminate or exclude muskrats from his pond. The varied conditions under which the muskrat is found have resulted in the presentation of much controversial information. Many conclusions have been reached concerning this furbearer and its relation to such habitat types as marshes, sloughs, lakes, and streams. Without question the thousands of farm ponds throughout the midwest provide an additional habitat type of importance. While this study was initiated to investigate muskrat-farm pond relationships, including productivity, mortality, movements, and

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selection of ponds for denning, additional investigations were carried on in one large marsh and in areas at the mouths of two streams entering the Mississippi River.

In June 1946, an area comprising approximately 12 square miles in Boone County, Missouri, was selected as a study site. This area, typical of the northern fringe of the Ozark uplands, consists of gently rolling hills interspersed with permanent and intermittent streams. Muskrat habitat consists of 40 ponds varying in size from 1/25 of an acre to 8.5 acres, 3.5 miles of permanent streams and 5.5. miles of intermittent streams. The study on this area extended from 1946 to the fall of 1948.

From 1947 to 1949 an area in Navigation Pool 24 on the Mississippi River near Clarksville, Missouri, was studied to determine the effects of winter drawdowns on muskrat populations. During the same period a study was conducted on the Squaw Creek Migratory Waterfowl Refuge in northwest Missouri to obtain comparative data from a marsh.

METHODS

A total of 370 animals were live-trapped, tagged, and released during this study. The handling and tagging of muskrats followed the methods described by Aldous (1946). To increase the chances of recovery, all animals were tagged in both ears.

Several methods of capturing live animals were tested during the first year of the study. Single- and double-door National traps, Havahart Humane traps, Gibbs live-traps, and floating drop-cage traps were used. At first, floating traps (Arthur, 1931) were found to be the most efficient in taking muskrats, but were discarded during the second year in favor of the less bulky National type. This small trap was most effective when placed in a trench dug in the pond bank and then covered with vegetation and baited. A colony trap, developed by Snead (1950), was used along the Mississippi River. As many as 12 animals were caught in one night in a collapsible model of this trap.

Live muskrats were taken in the Squaw Creek marshes with a portable enclosure made of 30 feet of 4-ft. welded wire fencing of 1 by 2 inch mesh. A wooden post was nailed to the fencing every five feet. With this a muskrat house was encircled and the posts were driven deep into the mud, so that no escape routes were left between the bottom of the fence and the marsh floor. The house was then opened, and the animals plunging out were confined within the enclosure. They were captured by hand, being seized by the tail as they swam along the fence. As many as 13 animals were captured from a single house in this way, and a total of 75 were taken in one week.

Tagged animals often showed a strong tendency to return to baited traps. When the number of animals on a pond exceeded the number of traps, difficulty arose in keeping out these bait-conditioned individuals. This problem was alleviated by transferring the animals caught in early evening to holding pens and then resetting the traps. By this means, 21 animals were taken from an 8.5-acre lake in one night, using only ten traps. Eleven of these had been taken one or more times previously.

A variety of baits were used, including

carrots, apples, lettuce, cabbage, turnips, oil of anise, and oil of peppermint. As Takos (1943) found, carrots were usually the most effective bait, but on the Squaw Creek marsh nuts and tubers of lotus, currently being used as food, proved very effective. Pre-baiting an area for a period of 5 to 7 days, as described by Chitty (1942), and Chitty and Shorten (1946), increased the efficiency of live-trapping.

All animals were sexed, weighed, and aged at the time of capture. The sex of young animals was determined by visual examination of the genital region; sex in adults was distinguished by palpation of the urinary papilla, as described by Dozier (1942). Weight was obtained by the use of a spring scale, with the animal in a sack of known weight. Age was determined by size at the time of first capture when, with but few exceptions, the animal was obviously either adult or young.

During the second year of the study (1947), an attempt was made to improve Dozier's (*op. cit.*) sexing technique. Dozier has stated "the relatively long and solid penis of the adult male can be felt within the sheath. . . ." Hamilton (1946) later described the penis bone found in muskrats. This bone can be felt on muskrats of any age by palpation of the urinary papilla between the thumb and first finger. December autopsies of animals previously live-trapped and sexed by this technique showed the method to be 100 per cent accurate.

To facilitate the recovery of tagged animals, steel trapping was conducted on the pond and stream study area during the legal trapping seasons in 1946 and 1947. Traps were straight spring Nos. 1 and 1½, straight spring stop-loss No. 1, jump stop-loss No. 1, and coil spring No. 1½. The last-named proved to be the most efficient, permitting only an occasional "wring off."

At the time of steel trapping all animals were sexed, weighed, measured, and aged. Aging was done by the methods described by Errington (1939), Baumgartner and Bellrose (1943), and Lay (1945). All pelts were stretched in standard fashion and numbered for future use in aging studies (Shanks, 1948). Returns from tagged animals on the Squaw Creek area were obtained through the annual refuge trapping program. No returns on animals tagged in Navigation Pool 24 were obtained, although 126 animals were steel-trapped on this area by independent trappers.

FINDINGS

During the study in the pond and stream area, 183 animals were live-trapped, tagged, and released—103 being tagged in 1946, 69 in 1947, and 11 in 1948. These animals were retaken a total of 298 times. During the first year of the study, 158 recaptures showed only three significant movements since being tagged earlier in the year. Of 130 recaptures during the second year of the study, 9 showed significant movements, while 3 additional movements were by animals tagged the previous year. The above recaptures include those animals which were steel-trapped during the legal trapping season.

Of a total of 298 retakes in live-traps and steel-traps, only 15 provided records of wanderings beyond the limits of the original home range. Among these were 11 movements from one pond to another (maximum distance, 1/2 mile), one from a pond to a stream (a distance of at

TABLE 1.—MUSKRAT POPULATIONS OF 40 PONDS AND 9 MILES OF STREAM

Month	Muskrat Colonies			Transient Animals			Totals	
	Ponds	Streams	Total	Ponds	Streams	Total	Ponds	Streams
July '47.....	8	7	15	6	6	12	14	13
August.....	10	7	17	1	7	8	11	14
September....	9	7	16	2	7	9	11	14
October.....	9	7	16	2	6	8	11	13
November...	8	12	20	3	2	5	11	14
December...	11	11	22	0	0	0	11	11
January '48 .	8	8	16	0	0	0	8	8
February....	7	..*	..*	2	3	5	..*	..*
March.....	4	4	8	3	5	8	7	9
April.....	3	3	6	1	4	5	4	7
May.....	2	10	12	0	0	0	2	10
June.....	2	8	10	0	0	0	2	8
July.....	2	8	10	0	3	3	2	11
August.....	3	6	9	0	5	5	3	11
September...	4	6	10	1	6	7	5	12

* Ice and snow prevented census.

least 2 miles), one from a pond to a stream and return, and one from a pond to a pool in an intermittent stream. It is known, however, that other animals moved, for three ponds in which young were produced in 1946 and four ponds in which young were produced in 1947 were completely vacated during the fall shuffle. Simultaneously, three ponds uninhabited in summer acquired animals during the fall of 1946, and five such ponds acquired animals during the fall of 1947.

It can be seen from Table 1 that muskrat populations are comparatively stable during the summer and winter, and that movement occurs primarily in the spring and fall. The population make-up of ponds after the completion of the fall movement gives some insight into the causes of these migrations. Among 40 ponds visited during the summer of 1946, 12 contained resident adults with young (Table 2). After the fall dispersal, only three ponds contained resident adult animals with their young; one pond contained an adult female and a young male; five ponds each contained one young male and one young female; and each of two ponds contained a young female only. The three ponds which held both adult and young into the winter months were more than two acres in area.

In general, we can conclude that a pond-dwelling female produces her first

TABLE 2.—COMPARISON OF MUSKRAT POPULATIONS FOR THREE YEARS IN CENTRAL MISSOURI

	1946	1947	1948
Number of ponds containing breeding populations (July).....	12 (13 litters)	8 (9 litters)	2 (2 litters)
Average number of muskrats per pond containing animals.....	9.3	5.1	..*
Average number of young muskrats per pond containing animals.....	7.7	4.0	..*
Colonies of muskrats found on 9 miles of stream .	6	7	8

* Insufficient data.

and only litter in mid-spring. Her young remain on the pond until they reach the age of five to eight months, when migratory activities begin. The adults sometimes migrate with the young. While it is believed that the initial movement is the result of population pressure, sex recognition soon plays a part, because most ponds by late fall harbor a pair. Although scanty, the data suggest that the female arrives in the pond first and is later joined by a male. Ponds in which one animal alone was found supported a female. One female was retrapped eight times during the month of November before being joined by a male. Once these pairs are established, they remain for the winter unless there is winter mortality. With the advent of the breeding season in late winter, however, so many ponds contain but one animal that a spring shuffle is necessary for restoration of pairs.

Assuming that the population density of the surrounding area is equal to that on the study area, and knowing the gain as well as the loss in individuals to the study area, it becomes possible to compute the net loss resulting from the fall shuffle. By mid-October the random fall wanderings begin, and most animals become settled in their wintering dens by late November. The advent of this fall movement is easily determined by the sudden drop in numbers of retakes of tagged animals. Since a large percentage of these tagged animals are never again retaken, it can be concluded that one of two things has happened:—either these migrants are moving so far off the study area that returns do not occur; or they are dying.

The number of untagged animals gained by the area does not equal the loss of tagged animals. By September 30, 1946, the study area contained 83 tagged animals (after subtracting losses of animals which died in live-traps). During December steel-trapping, 34 tagged animals were retaken and 49 were not accounted for—this represents the maximum possible egress. During this same steel trapping, 27 untagged animals were taken from the area—this represents the ingress. The difference (22 animals) is the probable net loss among migrating animals on the area. This loss of 45 per cent may represent mortality resulting from highway kill and increased vulnerability to predation. This computed net loss of 22 individuals is actually only 27 per cent of the total original population of 83 animals.

The existence of this mortality immediately raised the question—would it be advisable to establish an earlier season, allowing the trapper to harvest the crop prior to the fall migration and resultant mortality loss? To answer this, it was necessary to know the value of such early pelts. Accordingly, ararangements were made with the U.S. Fish and Wildlife Service to steel-trap a sample at the Squaw Creek Refuge during each of the fall months. All animals taken were skinned and stretched in standard fashion, using wire stretchers. Each pelt was labeled (in code) for reference as to location and date of capture. The entire collection was graded and evaluated by an experienced grader at a large St. Louis fur-house. The grader was not informed of the time or place of capture of the animals, and the code label gave no clue. The results are shown in Tables 3 and 4.

To insure the trapper a greater num-

ber of pelts, an open season prior to the advent of the fall shuffle would be required. Such a season would insure a larger harvest but a lower monetary return to the trapper. In October 100 pelts would have a value of $124.00. If trapping were postponed until December, the resulting population loss of 27 per cent would leave 73 harvestable animals, with a value of $217.54, or a net monetary gain of 75 per cent for the trapper. Unless muskrat mortality exceeded 60 per cent between October and December, the muskrat trapper during this year would have suffered no loss from the postponed open season. Since the computed net loss of 27 per cent on our study area was much less than this, it is obvious that a December season is preferable to an October season.

TABLE 3.—EFFECT OF MONTH OF CAPTURE ON PELT VALUE OF MUSKRATS

Month	Number Examined	Value	Increase over September
September...	22	$0.90	..
October.....	25	1.24	38%
November...	18	1.70	89%
December ...	25	2.98	202%
Total	90		

TABLE 4.—PELT VALUES OF FALL-TRAPPED MUSKRATS

Grade	Month When Caught			
	Sept.	Oct.	Nov.	Dec.
No. 1 Large.....	..	..	..	7
No. 1 Medium....	..	..	1	13
No. 1 Small.....	..	..	..	4
No. 2 (Size).....	1	7	11	..
No. 2 (Quality) ...	4	8	4	..
No. 3.....	14	4	1	..
Kits.....	3	5	2	1

No significant movement for animals tagged on the Squaw Creek marsh was found. During the winter trapping season a 44 per cent return was obtained from 100 tagged animals, as compared to a 38.5 per cent return from 83 tagged animals on the pond and stream area, thus suggesting a lower mortality for the more sedentary population. This may not be a significant difference, however, because the Squaw Creek sample was tagged in September and the pond and stream sample was tagged during the summer months.

Analysis of recaptures of live-trapped animals gives some insight into the territorial behavior of muskrats inhabiting Missouri streams. An understanding of this behavior is of particular value to the game manager who attempts to use muskrat sign as an index to population trend. Figure 1 shows the extent of movement of retrapped muskrats. It will be noted that around each summer den is clustered a group of points showing where animals were originally taken in live-traps and where they were recaptured. It is of special interest that there was no evidence of overlap in the summer cruising range of animals from adjacent colonies. This suggests that territorialism is the factor responsible for the limits of movement of muskrats from any colony and that this movement will be approximately one-half the distance between adjacent colonies. Additional evidence supporting this belief was found in two other streams studied.

The importance of this conclusion is evident when we consider how frequently muskrat population trends are determined by searching for sign at stream—road intersections. If point X on the map shown in Figure 1 were visited, sign would be evident. If colonies C and D were exterminated before the next year, sign would again be found at

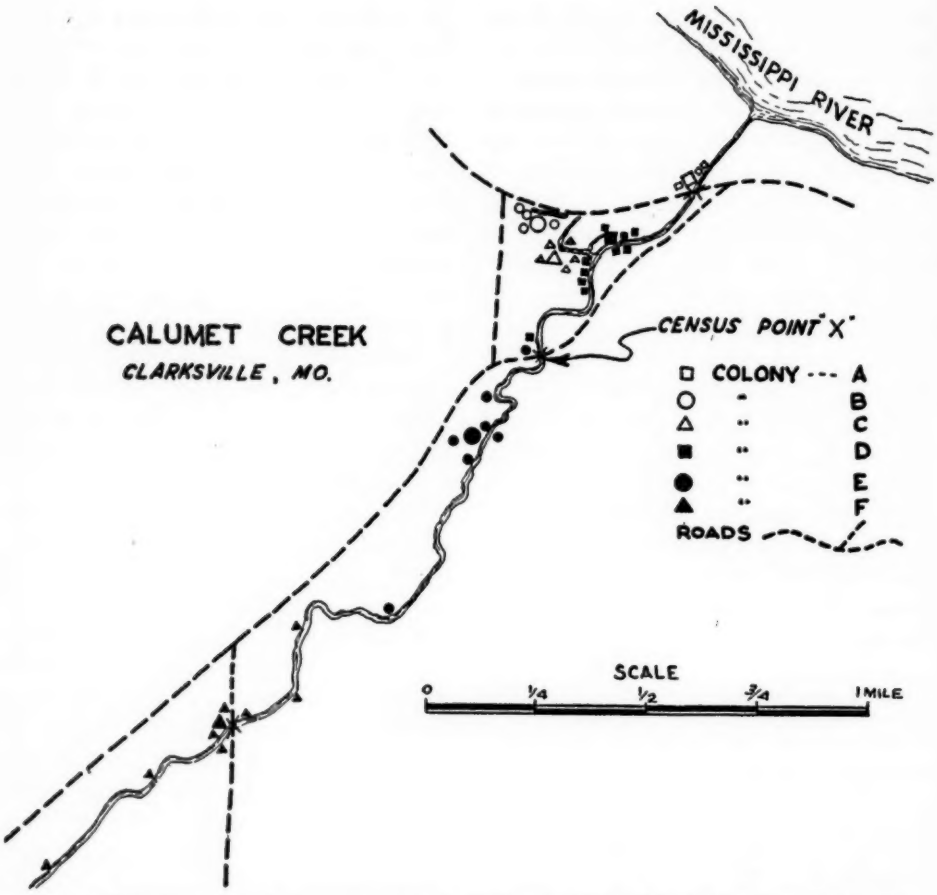

FIG. 1. Distribution and summer range of muskrats along a Mississippi River tributary.

point X, due to the movements of muskrats from colony E. Thus a 50 per cent decline in muskrats would not be evident to the casual worker.

During the period of study there have been many observational notes and facts recorded, none of which can be presented in tabular or graphic form. In the discussion which follows, these observations will be used to support data presented above. The more important of these observations are as follows:

No young have been found to be born in farm ponds after June 15. This is based on a continuous study of 22 ponds which contained breeding adults.

A pond of less than one acre supports but one female, and she produces only one litter. Animals inhabiting these small areas are more likely to wander than are those living in larger ponds.

Any suitable site, such as a pond or stream pool, contains its maximum number of muskrats when the population is most stable, in June and July.

No correlation has been found be-

tween numbers of muskrats in ponds and the type or kind of vegetation to be found on any given pond. The same conclusion was reached by Greenwell (1948) in his study of Missouri farm ponds.

In following the tracks of wandering stream animals during the fall and early winter a general downstream movement was detected; this movement is greatest during November.

Only in rare instances are ponds containing young animals found also to hold an adult male. This probably means that the males wander off in search of other females soon after mating. In one instance two ponds, located one mile apart, each held an adult female with a litter of young. Midway between the two was a third pond which contained a solitary adult male. It was quite possible that this male served both females. The fact that these males wander widely may account for the failure of females to conceive a second time. Farm pond muskrats are probably polygamous, as indicated by a winter harvest of 62 per cent females, none of which was barren.

DISCUSSION

Returns from tagged animals indicate one point rather conclusively: migration of pond animals is predominantly from pond to pond, with no indication of animals reared on streams moving to a pond site during the course of this study. Stream animals tend to spread out along the streams during the fall months, with some concentration of animals at certain points. Since muskrats wintering in farm ponds have a shoreline habitat limited to the size of the pond, and since the majority of ponds contain only one pair by December 1, it may be seen that winter trapping will reduce pond animals more rapidly than stream animals. This is illustrated in Table 2, showing that the number of ponds supporting adult females has steadily decreased during the three years of the study, while stream colonies have shown a slight increase. It thus appears that pond animals represent a population type which tends to remain in ponds, while stream animals tend to remain in streams.

It is obvious that originally farm ponds must have gained their populations from nearby streams. The extent to which this type of movement now occurs is undoubtedly affected by the population pressure. It is possible that, with a high population in streams, stream-to-pond movement would be greater than was found in the present study, when the population was admittedly low. The conclusions reached, therefore, are applicable only to low densities and may not apply to high populations.

There is no discernible reason why muskrats choose a certain pond in preference to another. Unfenced ponds, subject to heavy use, were frequented by muskrats as often as were fenced ponds. Ponds with good stands of emergent aquatic vegetation were not used in any greater frequency than ponds entirely devoid of emergent vegetation. It appeared obvious throughout the study that selection of a pond by muskrats was entirely random. One exception is the adult female that has produced a litter, wanders from the pond in the fall, but returns to the same pond the following spring to produce another litter. It is evident, therefore, that the

control of muskrats in a farm pond is not a problem of habitat manipulation.

It has been suggested that damage to a pond dam by muskrat denning might be eliminated by making another portion of the shoreline more attractive to them. If this were accomplished, there would still be two reasons why the dam might not be free of their burrows: first, they tend to establish small dens which are apparently used as feeding stations, entirely separate from the main den. These feeding dens are usually so shallow that the danger of immediate damage is slight; second, tagging studies indicate that young-of-the-year, after spending a period in the parental den, will establish a den of their own, which may be an extension of a previous feeding den, or an entirely new one. During the study, as many as three dens have been found in a pond only 50 feet in diameter. It would seem that the only certain means by which muskrats can be kept from a dam is by the use of mechanical obstruction which their digging prowess cannot overcome.

It is the opinion of the authors that there is no practical way to keep muskrats out of a pond; likewise, there is probably no ecological means by which they can certainly be kept out of the dam. The problem, then, becomes one of constructing the pond so that damage is reduced to a minimum. As pointed out by Nagel (1945), this entails three things: first, a freeboard on the dam of at least three feet, which will allow ample room for denning activities; second, a spillway of sufficient width and slope to prevent the water level from rising more than a few inches during excessive rains; and third, fencing to exclude livestock from the pond, thus preventing caving in from trampling.

In the case of landowners who want muskrat-free ponds, it is suggested that the adult animals be removed by trapping in the spring before litters are born and after the spring dispersal is over. Removal before the spring dispersal would merely make room for other animals to move in.

For the commercial trapper well-located large ponds (two or more acres in size) are recommended as refuge areas. Impoundments of this size are not subject to the population pressure of the smaller ponds during the fall months and will usually hold their summer population over winter. With the arrival of the breeding season, the territorial behavior of the animals remaining will force all but one or two breeding pairs to leave in search of unoccupied denning territory, thus restocking the surrounding ponds.

For the farmer a December season offers only temporary relief because the removal of two muskrats in December merely makes room for two more the next spring. The data on hand are not adequate for a discussion of a spring trapping season in Missouri. Nevertheless, if future study should show a spring season to be economically and biologically practical, as in Canada, then by the mere tool of regulation the trapper would be able to take high quality pelts from ice-free waters, while the farmer, if he desired, could legally remove troublesome animals from his pond at the best possible time to insure profit from pelts and lessened hazards from damage to the pond dam.

SUMMARY

Muskrat populations in 40 farm ponds

and 9 miles of stream were intensively studied during this study. Additional studies were made in one large marsh area, and in a slough and stream area on the Mississippi River.

During this study, 370 muskrats were live-trapped, tagged in both ears, and released in three study areas. Conclusions concerning movements of these animals are based on approximately 400 recaptures in live-traps, 100 terminal captures in steel traps, and continuous observations of the distribution of muskrat sign.

The following attributes were found to be characteristic of muskrat populations on farm ponds of less than one acre in surface area: (1) never more than one litter of young was produced; (2) animals dwelling in these small ponds were much more likely to migrate than animals in larger ponds; (3) adult males were rarely found in association with adult females and their young; (4) maximum numbers were found during June and July; (5) no young were ever found born after June 15; (6) no correlation was found between vegetation of a pond and its use by muskrats.

Pond muskrat populations were found to be distinct from stream populations, the primary type of migration being from pond to pond. Two migratory peaks occur: one in the fall, and one in the spring. Egress exceeded ingress on this area by 45 per cent, resulting in a net loss to the area of 27 per cent. Relative values of fall and winter trapped muskrats were determined, showing December-caught pelts to be of enough greater value to offset the reduced size of catch resulting from the fall shuffle. The causes of these seasonal movements are discussed.

There is no apparent means of manipulating habitat to control muskrats in farm ponds, it being feasible to exclude them only by spring trapping. Farm pond populations can be increased by setting aside large impoundments (two acres or more in area) as refuges.

Stream-dwelling muskrats appear to be territorial to the extent that the summer range of colonies is equal to approximately one-half the distance between adjacent colonies.

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FOOD HABITS OF MULE DEER IN UTAH

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The present controversy between public land administrators, stockmen, and sportsmen over the assignment of range has emphasized the need for more information concerning the complex relationships in use of forage by grazing animals.

In 1946 a cooperative project[1] was organized to study big game, livestock, and range relationships in Utah. The investigation herein reported on was a phase of the above project aimed at determining seasonal forage habits of deer. All areas of observation are in central Utah within or adjacent to the Fishlake National Forest.

REVIEW OF LITERATURE

Forage preferences of mule deer are influenced by several factors among which species availability and time of year are very important. In the case of many species, particularly forbs and grasses, availability is largely determined by time of year. Aside from the question of availability, the abundance of a species has a great deal to do with its preference rating. Because the abundance of a species in relation to the abundance of all other species with which it is associated varies so widely from one locality to another, findings of a food habits study may have local application only. Perhaps the one food habit characteristic that may have general application to a big game species is the one expressing the part played by browse, forbs, and grass in the total diet at a given season. Even this cannot always be expressed categorically.

Dixon (1934) and Robinson (1937) found that forbs occupied the most prominent place in the summer diet of mule deer and gradually gave way to browse as summer progressed into fall.

A study in northern Arizona by Rasmussen (1941) showed that summer food was made up mainly of forbs and a few shrubs; grass made up less than 10 percent of the diet even when preferred foods were scarce.

Carhart and Coutts (1941) and Carhart (1944) reported that browse was the principal food in all seasons and that forbs never made up much of the diet although they were taken year-long. The results of these investigations were largely obtained from stomach-content

[1] The Utah Cooperative Big Game, Livestock, and Range Relationship Research Project is conducted jointly by the Utah State Fish and Game Commission, U. S. Fish and Wildlife Service, Utah State Agricultural College, and U. S. Forest Service.

analyses. However, some of the dangers involved in the determination of food habits from stomach analyses were pointed out by Murie (1933), while Norris (1943) proved conclusively that stomach contents cannot be used as a quantitative measure of forage consumption because of the fact that coarse browse accumulates in the stomach over a period of days whereas succulent forage is rapidly digested. Stomach samples, therefore, are particularly unsuitable for quantitative measurement of forage consumption during the spring and summer.

De Nio (1938), Cliff (1939), Edwards (1942), Fischer, *et al.* (1944) and other deer forage investigators are agreed that the winter diet of mule deer consists mainly of shrubs and that the greatest consumption of green grass takes place in the spring. A survey in California by the Interstate Deer Herd Committee (1947) showed that considerable quantities of dry grass were taken throughout the winter when it was not covered by snow.

Nichol (1938) made one of the more detailed deer food habits studies in Arizona. He concluded that forbs and grass do not generally receive full recognition of their true importance although he made no attempt to minimize the value of browse in the diet. In Utah, Smith (1950) has conducted some pen-feeding experiments using native browse plants.

METHODS

Weight and utilization of herbage were estimated by species on permanent circular plots of either 48 or 96 square feet, spaced at random or at regular intervals along lines which were similarly spaced within each vegetal type. The small plots were used where the vegetation was dense, the large ones where it was sparse.

Weights were determined by the weight-estimate method described by Pechanec and Pickford (1937a). The method used to determine utilization was the ocular-estimate-by-plot supplemented by a modified volume-by-weight method (Pechanec and Pickford, 1937b).

The word, "diet," is used in the following discussion to represent the total forage consumed as computed from the observations made. Obviously, the actual deer diet may have included one or more species that did not occur within the immediate area of observation. However, it is believed that the sample taken in each vegetal type was large enough to preclude the possibility of missing any species that made up an appreciable part of the total volume.

SUMMER FOOD HABITS

Data on summer range were obtained during early July, mid-August, and early October and cover the period 1947–50, inclusive. The line of demarcation between seasons is obviously not sharp and the October observations are indicative of early fall as well as late summer feeding activity. Four vegetal types were studied—spruce-fir, aspen, browse, and silver sage-grass. Of these the first three are important summer forage types and observations in them were therefore more extensive than in the silver sage-grass type.

Spruce-fir.—Observations in this type, which occurs mainly on steep, northerly slopes, were made at three locations averaging 9,300 feet elevation. Principal tree species are Engelmann spruce (*Picea engelmanni*), white fir (*Abies*

concolor), and Douglas-fir (*Pseudotsuga taxifolia*). Aspen (*Populus tremuloides*) is associated with the conifers in many areas. The understory consists mainly of snowberry (*Symphoricarpos* spp.), creeping mahonia (*Mahonia repens*), myrtle pachistima (*Pachistima myrsinites*), heartleaf arnica (*Arnica cordifolia*), clover (*Trifolium* sp.), penstemon (*Penstemon* sp.), sedge (*Carex* sp.), and nodding brome (*Bromus anomalus*).

Aspen.—Very extensive areas between the oakbrush zone and the coniferous forests are occupied by aspen. Observations in this type were made at four locations averaging 9,300 feet elevation. The understory is made up largely of big sagebrush (*Artemisia tridentata*), creeping mahonia, common juniper (*Juniperus communis*), snowberry, heartleaf arnica, dandelion (*Taraxacum officinale*), clover, penstemon, lupine (*Lupinus alpestris*), monardella (*Monardella odoratissima*), sedge, bearded bluebunch wheatgrass (*Agropyron spicatum*), and nodding brome.

Browse.—The browse type was observed at four locations averaging 9,400 feet elevation. It is characterized by big sagebrush, snowberry, chokecherry (*Prunus virginiana*), lupine, penstemon, tall bluebells (*Mertensia leonardi*), dandelion, bearded bluebunch wheatgrass, mutton bluegrass (*Poa fendleriana*), Letterman needlegrass (*Stipa lettermani*), and mountain brome (*Bromus carinatus*).

Silver sage-grass.—One observation was made in this type at an elevation of about 9,200 feet. Silver sagebrush (*Artemisia cana*), dandelion, bistort (*Polygonum bistortoides*), cinquefoil (*Potentilla filipes*), red fescue (*Festuca rubra*), sheep fescue (*F. ovina*), sedge, and Letterman needlegrass are the principal species.

Utilization was recorded on 104 species of plants on the summer range. Of these, 23 were browse species, 64 were forbs, and 17 were grasses and sedges.

Those species which made up one percent or more of the deer diet at one or more of the three observation periods are listed, for the three principal vegetal types, in Table 1 together with data showing their abundance. The figures which express herbage and diet for a particular month in a particular type are derived from a consolidation of all data collected for that month in that type. Each type, except the silver sage-grass is represented by observations made at different locations, e.g., the spruce-fir type was observed at three different locations and the data combined to express the results for the type as a whole. Obviously the herbage composition would not be identical at each location even though the locations would all be classified as the same type.

Observations were not made for all periods of time at every location. For example, in the browse type the only observation made at the location which had a high percentage of oak was in October. Oak also occurred in other locations in the browse type which were observed in July and August, but it was not abundant enough in these locations to make one percent of the herbage.

It is evident from this table that 8 species or fewer composed two-thirds or more of the diet at each of the three observations in each summer range type. The only exception is the July observation in the browse type, and in this case 7 species accounted for 62 percent of the diet. On the basis of an average for the

TABLE 1.—VEGETAL COMPOSITION AND DEER DIET ON SUMMER RANGE, UTAH, 1947–50. (Herbage figures are given in percent of total available as determined by weight estimates, diet in percent of total forage consumed as determined by weight and utilization estimates.)

Species	Aspen type						Spruce-fir type						Browse type					
	July		August		October		July		August		October		July		August		October	
	Herbage	Diet	Herbage	Diet	Herbage	Diet	Herbage	Diet	Herbage	Diet	Herbage	Diet	Herbage	Diet	Herbage	Diet	Herbage	Diet
Amelanchier sp.	T*	1	2	4	1	1	2	0	1	T	4	2	T	T	..	..	..	..
Artemisia cana	3	4	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Cercocarpus ledifolius	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3	3
Cornus stolonifera	..	..	..	..	..	..	3	T	2	3	7	13	..	..	..	..	..	..
Mahonia repens	7	1	13	T	13	0	7	4	8	2	9	1	..	..	..	..	..	..
Physocarpus malvaceus	..	..	..	..	..	..	1	T	T	1	3	4	..	..	..	..	..	..
Populus tremuloides	9	16	10	8	4	27	16	9	29	29	7	11	T	2	T	1	T	0
Prunus virginiana	T	T	T	4	..	..	..	..	..	..	..	..	4	13	7	26	2	0
Quercus gambelii	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	35	72
Rosa sp.	1	1	2	5	2	3	3	1	2	2	5	7	T	2	..	..	..	..
Salix spp.	..	..	..	..	..	..	1	1	T	1	3	9	..	..	..	..	..	..
Sambucus glauca	T	T	T	T	T	5	2	4	1	3	2	14	T	8	..	..	T	T
Symphoricarpos oreophilus	2	1	3	2	2	6	9	1	7	1	22	21	13	2	15	0	5	4
Actaea arguta	..	..	..	..	..	..	T	1	T	2	1	4	..	..	..	..	..	..
Arnica cordifolia	2	3	T	0	..	..	9	6	9	9	11	1	..	..	..	..	..	..
Balsamorhiza sagittata	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	3
Castilleja linariaefolia	T	5	1	12	1	4	1	16	T	8	..	..	T	2	1	5	T	0
Cirsium sp.	T	3	2	11	2	4	4	0	3	T	..	..	..	..	..	..	..	..
Ligusticum porteri	T	3	T	23	1	0	T	T	T	T	T	1	T	2	..	..	..	..
Lupinus alpestris	T	0	T	2	6	27	..	..	1	T	..	..	1	18	6	57	T	T
Mertensia leonardi	1	0	..	..	..	..	1	T	T	0	..	..	4	5	..	..	..	..
Penstemon watsoni	1	1	2	12	1	T	2	2	2	4	2	1	3	11	8	5	T	0
Taraxacum officinale	3	4	T	T	T	0	..	..	..	..	..	..	2	4	3	1	T	T
Trifolium sp.	5	34	..	..	..	..	8	46	6	17	..	..	..	..	..	..	..	..
Agropyron spicatum	1	0	2	T	3	0	..	..	..	..	..	..	T	0	..	..	12	4
Carex spp.	5	T	6	T	5	3	2	2	3	2	1	1	..	..	..	..	2	2
Poa fendleriana	5	2	4	1	5	1	T	2	..	..	..	..	3	2	2	0	8	6
Stipa columbiana	T	0	..	..	T	4	T	T	..	..	..	..	T	1	..	..	T	T
Stipa lettermani	1	0	T	T	..	..	T	T	T	T	T	T	8	3	3	0	T	T
Total	46	79	47	84	46	85	71	95	74	84	77	90	38	75	45	95	69	94

* Indicates less than 1 percent.

summer for each type, 8 species or fewer composed three-fourths or more of the deer diet, whereas the remaining one-fourth or less was provided by a large number of species whose individual contribution was small. The few species that made up most of the diet represented about one-fifth of the total herbage in the aspen type, one-third in the browse, and one-half in the spruce-fir. This wide difference between the abundance of a species in the diet and in the vegetal composition is best illustrated by *Trifolium*, *Lupinus*, and *Ligusticum* in Table 1.

Some plants were utilized throughout the entire summer grazing season in one vegetal type or another. These included aspen, rose (*Rosa* sp.), elderberry (*Sambucus glauca*), snowberry, paintedcup (*Castilleja linariaefolia*), ligusticum (*Ligusticum porteri*), lupine, penstemon, bluegrass, and sedge.

Other species, not shown in the table, were used only in early or late summer. The early ones included yarrow (*Achillea lanulosa*), fleabane (*Erigeron* sp.), eriogonum (*Eriogonum racemosum*), sweetroot (*Osmorhiza divaricata*), and starwort (*Stellaria jamesiana*); the late ones included big sagebrush, pachistima, and currant (*Ribes cereum*).

As recorded in Table 1, the ten species most prominent in the total summer diet include five browse and five forb species. They are aspen, chokecherry, oak, elderberry, snowberry, paintedcup, ligusticum, lupine, penstemon, and clover.

Additional plants which either did

not occur on the study plots or were not sufficiently abundant to provide an appreciable portion of the diet, but which showed a consistently high degree of utilization are monkshood (*Aconitum columbianum*), bittercress (*Cardamine cordifolia*), geranium (*Geranium* spp.), agoseris (*Agoseris* spp.), and phacelia (*Phacelia* spp.).

In the less important silver sage-grass type a single observation was made in July. Although forbs made up only 14 percent of the vegetal composition in this type, they accounted for the entire deer diet with dandelion representing nearly half. Other important foods were fleabane, clover, bistort, and an unidentified crucifer.

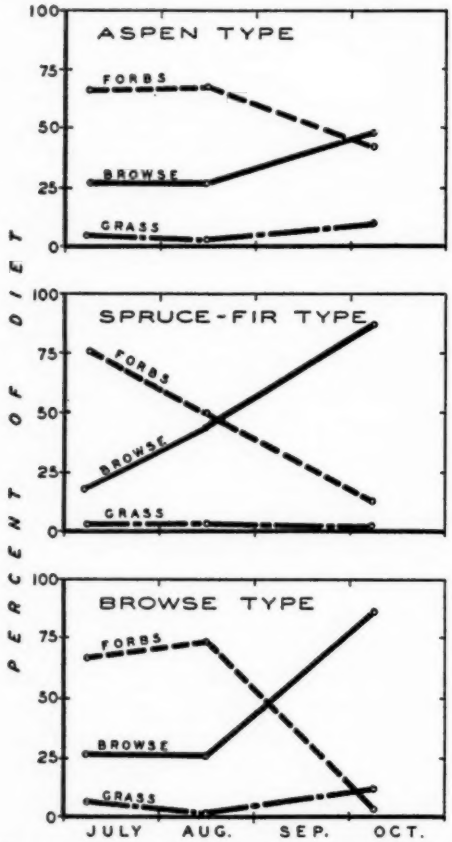

FIG. 1. Composition of summer deer diet, by classes of vegetation, in three vegetal types, Utah, 1947–50.

The importance of each of the three classes of forage in the summer diet is illustrated by the graphs in Figure 1. These show the percentage each forage class made of the total use recorded at each of three stages during the summer grazing season.

The most prominent place in the early diet in each type was occupied by forbs which maintained their position until after mid-summer and were then gradually replaced by browse species. On the other hand, browse made up only about one-fourth of the early diet, but increased in importance until by late summer it accounted for nearly 85 percent of the diet in the spruce-fir and browse types and exceeded forbs by a small margin in the aspen. This small difference between the positions of forbs and browse in the aspen type may be explained by the fact that forbs remain succulent longer there than in the other types. Stomach samples taken in the aspen type in late October and early November, when forbs were dry, showed that browse had assumed approximately the same importance there that it had in late summer in the spruce-fir and browse types. Grasses and sedges maintained a low, but fairly constant place in the diet throughout the summer. The similarity of the relationships between the three forage classes in each type indicates that type has little, if any, effect on summer forage preferences of deer.

The summer-range types, while not considered excellent from the standpoint of forage abundance and selection, were not so severely depleted that deer were

forced to consume any particular forage because they had no choice. Browse made up the largest part of the herbage in each type.

In view of the generally accepted belief that deer are essentially browse eaters it is significant that forbs are far more important than browse in the diet during the period of time that they remain succulent.

WINTER FOOD HABITS

Data on winter utilization were recorded in late April and cover the winter of 1948–49. Observations were made at two locations in the juniper-sage type averaging 6,500 feet elevation. This type consists mainly of juniper (*Juniperus utahensis*), big sagebrush, cliffrose (*Cowania stansburiana*), bitterbrush (*Purshia tridentata*), pinyon (*Pinus cembroides edulis*), and oak (*Quercus gambelii*). Forbs and grass together represent about 4 percent of the total forage available.

Nearly all forbs and grasses on the winter range are in a dry condition at the onset of winter and hence are easily broken and smashed. In many places, they may be completely covered by snow. Because it is practically impossible to judge utilization under such circumstances only the browse species were considered in these observations.

Twenty-five species of browse were utilized. Seven of these accounted for 97 percent of the winter diet. Plants which made up one percent or more of the vegetal composition or of the deer diet are listed in Table 2. *Purshia*, with 36 percent of the current growth eaten, shows a higher degree of use than any other species. The fact that 64 percent of the current growth of *Purshia* remained on the plants after winter utilization is evidence that selection of species was not unduly influenced by their scarcity.

TABLE 2.—VEGETAL COMPOSITION, UTILIZATION, AND DEER DIET ON WINTER RANGE, UTAH, 1948–49

Species	Total herbage	Weighted utilization	Total diet
	Percent	*Percent*	*Percent*
Artemisia tridentata	29	10	37
Cercocarpus montanus	1	24	3
Chrysothamnus nauseosus	1	4	T*
Cowania stansburiana	6	31	25
Ephedra sp.	1	T	T
Gutierrezia sarothrae	1	T	T
Juniperus utahensis	46	1	8
Pinus cembroides	2	1	T
Purshia tridentata	4	36	21
Quercus gambelii	5	3	2
Rhus trilobata	1	1	1
Total.....	97		97

* Indicates less than 1 percent.

The importance of sagebrush, cliffrose, and bitterbrush is indicated by the fact that they made up only 39 percent of the total forage available yet they produced more than four-fifths of the total forage consumed.

SPRING FOOD HABITS

Utilization data from two areas in the juniper-sage type were combined to express the results in terms of spring use. These data were recorded in early June of 1949 and 1950. The herbage, which is 92 percent browse, 2 percent forbs, and 6 percent grasses, is made up largely of juniper, big sagebrush, pinyon, and mountain mahogany (*Cercocarpus montanus*). Forbs are extremely scarce on this range. Of 16 species observed, none were sufficiently abundant to constitute one percent of the total vegetation.

Table 3 lists the 13 species which were utilized together with their abundance in the type and in the diet.

TABLE 3.—VEGETAL COMPOSITION AND DEER DIET ON SPRING RANGE, UTAH, 1949–50 INCLUSIVE

Species	Total herbage	Total diet
	Percent	*Percent*
Amelanchier sp.	T*	T
Ephedra sp.	T	2
Astragalus convallarius	T	T
Castilleja angustifolia	T	T
Erigeron concinnus	T	T
Penstemon sp.	T	2
Solidago petradoria	T	1
Zigadenus paniculatus	T	1
Agropyron spicatum	T	T
Oryzopsis hymenoides	T	T
Poa fendleriana	3	82
Sitanion hystrix	3	1
Stipa comata	T	7
Total.....	6	96

* Indicates less than 1 percent.

The percentage of grass in the diet is probably exaggerated because there was strong evidence that a few sheep had grazed in the immediate vicinity of the plots on one area. There was, of course, no way to separate deer use from sheep use. However, there was no sign of sheep grazing on the other area and the grasses there made up three-fourths of the total use. This would certainly indicate that they occupy a prominent place in the deer diet at this season.

The selective nature of deer foraging activity is most strongly illustrated in Table 3 wherein 3 species which made up less than 7 percent of the total herbage provided 90 percent of the diet.

SUMMARY

The objective of this investigation was the determination of seasonal forage habits of deer in Utah.

Approximately 125 species were utilized, but the bulk of the seasonal diet (75 percent or more) consisted of 8 species or fewer in each case. These few species represented one-third or less of the total herbage available in all types except the spruce-fir where they made up about one-half.

Aspen, rose, elderberry, snowberry, paintedcup, ligusticum, lupine, penstemon, bluegrass, and sedge were utilized throughout the entire summer observation period. Yarrow, fleabane, eriogonum, sweetroot, and starwort were utilized only in early summer; big sagebrush, pachistima, and currant only in late summer.

The ten species that contributed most to the summer deer diet were aspen, chokecherry, oak, elderberry, snowberry, paintedcup, ligusticum, lupine, penstemon, and clover.

Forbs were far more important than browse in the diet during the period of time that they remained succulent.

In the three vegetal types where summer-long observations were made the most prominent forage class in the diet was forbs until after midsummer, then browse use gradually exceeded forb use. Grasses and sedges maintained a low, but fairly constant level in the summer diet.

Type had little, if any, effect on summer forage preferences of deer.

On the winter range, big sagebrush, cliffrose, and bitterbrush provided only 39 percent of the available herbage, but more than four-fifths of the total diet.

The greatest utilization of green grass took place in the spring, at which time it made up about 90 percent of the diet.

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SEX RATIOS IN PHEASANT RESEARCH AND MANAGEMENT

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The accuracy of many pheasant census methods often is impaired by lack of reliable techniques for determining sex ratio. In view of the preponderance of projects currently emphasizing the inventorying of pheasant populations, development of such techniques seems to constitute a major problem in research and management.

The present paper reviews some of the uses of sex ratios in interpreting population phenomena and discusses problems involved in obtaining accurate ratios. Although some of the principles here discussed have appeared elsewhere in the literature, it is evident that they have not always received the attention from workers in the field that their importance merits.

Sex Ratios and Crowing Cock Counts: When Kimball (1949) outlined the method for censusing pheasants by crowing-cock counts, he emphasized the need for taking into account the sex ratio of the population. This requisite is recognized by most workers, but often it is assumed that sex ratios are relatively stable from year to year, and that they can be neglected when the crowing-cock census is being used only as an index of population change. Even when the technician recognizes that the census is incomplete until it is corrected for sex ratio, press releases may report only the change in cock count from the previous year and imply that the percentage of increase or decrease reflects a like change in the entire population.

Permission has been granted to use the following material from crowing-cock censuses in Wisconsin in 1949 and 1950 (Thompson, 1950-a) to illustrate the importance of considering both sex ratios and statistical reliability of field data in determining annual trends.

From 1949 to 1950 the crowing-cock index in Green County dropped from 12.5 to 9.9, a decrease of about 20 percent; however, a more complete survey of conditions indicated that if this reflected an actual change in the abundance of cocks it did not necessarily result from a decrease in the pheasant population. Rather, it appeared that the total population in 1950 was equal to or possibly superior to that of the previous year.

For the two years, the observed sex ratio in spring surveys in Green County changed from 13 to 10.1 cocks per 100 hens, almost the same as the drop in crowing-cock index. From this it can be deduced that there was little if any change in the number of hens. Actually, if we could consider changes in crowing-cock index and the observed sex ratio as exactly representing changes in the population, a slight increase in hens would be indicated.

The above illustration is taken from unanalyzed data, since the problem of statistical analysis lies outside the scope of the present paper. It should be noted, however, that adequacy of the sample is of major concern in population studies. Unless basic data are statisti-

cally significant, no amount of mathematical manipulation will give valid conclusions. Acknowledgment is made to Earl L. Atwood for pointing out the following statistical aspects of the Wisconsin study.

Thompson (1950-b) shows that in the crowing-cock transects with ten to fifteen stops there was an accuracy of about plus or minus 4 percent when run only once. Thus the differences cited could very well have been a result of sampling error. The sex-ratio counts, however, were based on 615 observations in 1949 and 590 in 1950. Although the shift in observed ratio was slight (88.5 to 90.8), the probability that this change would arise from chance through sampling error is only about 12 out of 100, if we can assume that there was no bias in the method of taking the samples.

In other words, if the Green County data are considered statistically there is a good chance that no change occurred in the cock population, while probably there was a small increase in the number of hens.

A further example from the same report points up the fallacy of comparing two areas on the basis of cock counts alone. In Milwaukee County, where pheasants were protected, the crowing-cock index in 1950 was 23.0, about 2.3 times as high as for Green County in that year. Nevertheless, observed spring sex ratio in the protected area indicated that 52.82 percent of the population were cocks. Thus for some unknown unit area the 23 represented a total population of only about 44 pheasants, and of these only about 20 (47.2 percent) were hens.

In Green County the 10 cocks heard crowing comprised slightly more than 9 percent of the pheasants of the same unit area. Thus there is indicated a population of nearly 110 pheasants. Since over 90 percent of these are hens, the unit hen population would be about 100.

The greater number of cocks heard in Milwaukee County gives a false impression that under protection pheasants have increased well above those in the county open to hunting, yet the total population density in that county in 1950 evidently was less than half that in Green County, and the breeding stock of hens was only about 20 percent as high.

Not only do sex ratios differ between hunted areas and refuges, but there are variations correlated with the quality of pheasant habitat and with annual production. The spring sex ratio in heavily hunted areas seems to be directly related to pheasant density (Dale, 1951), and thus a higher percentage of hens can be expected following good breeding years. Unless the ever-changing sex ratio is taken into account, the crowing-cock count can be misleading.

Sex Ratio and the Harvest: Allen (1942) used a method of estimating pheasant populations from the change in sex ratio accompanying removal of a known number of cocks during the hunting season. This method is similar to that used by Kelker (1940) for estimating size of the deer herd from the change in buck-doe ratio as a result of a known kill.

There are difficulties in applying this technique that have limited its use. Seldom is the investigator sure that he knows the total kill of birds. Usually he must estimate the number of unretrieved kills, and in most places has

little information on the hen kill. Sometimes abnormal movements on or off the area complicate the picture. Most serious, however, is the problem of accurately estimating sex ratios before and after the hunt.

At Michigan's Rose Lake Experiment Station, where the method was developed for pheasants, hen kill was a minor factor. The cock kill was known, since all hunting was under permit and all bags were checked before hunters left the area. Under such close supervision, it was believed that all factors could be estimated with fair accuracy except the pre- and post-hunting season sex ratios. While the technique was believed to have value for estimating the population, Allen was never sure that his sex-ratio figures were sufficiently reliable to be dependable.

This technique was used by Harper, *et al.*, (1951) in California, in a study of pheasant populations under heavy hunting pressure. Here, also, workers had difficulty in ascertaining sex ratios, and there were some difficult patterns of open and closed areas and abnormally heavy cover. Nevertheless, population estimates checked closely with an estimate based on the Lincoln index for the same area. The technique seems to offer distinct possibilities, and used with accurate estimates of sex ratio, could be highly reliable.

Success of the Breeding Season: It has long been recognized that sex ratio is most divergent in adults and that it becomes equalized to a degree in the fall by the addition of a large number of young birds about even as to sex. Leopold (1945) recognized this fact in bobwhites, where normally the adult sex ratio becomes unbalanced by hen mortality but is restored in part by the annual crop of young birds to almost an even ratio in the fall. He further recognized that the degree of equalization is in proportion to the production of young birds, and hence could serve to indicate success of reproduction.

Such a relationship serves little practical purpose in quail because of the slight annual variation in fall sex ratio and the difficulty of ascertaining it accurately by field observations. Leopold found the young and adult males to comprise 53 percent of the fall population and cited evidence that this is about the usual percentage.

In pheasants, where adult sex ratios may be much more divergent, there may be a practical application of this relationship, although here, also, difficulty of obtaining accurate fall sex ratios will limit the places where it can be applied.

The exact proportion of males and females in young pheasants is not known. Latham (1947) found males to comprise about 53 percent in 1,000 day-old chicks, evidently partly as a result of higher mortality of females at the time of hatching. Hatchability of eggs in the field usually is higher than at game farms and consequently the numbers of males and females produced should be more nearly equal. He also found young hens to be more resistant to adverse conditions than males. The two opposing factors might well result in about equal production of hens and cocks by fall, a condition that is usually assumed by field observers. For the purpose of comparing production in different years it seems safe to make this assumption.

Then, the adult hen and cock popula-

tions will each be augmented in the fall by a number of young birds equal to half the production of young for the year. For the purpose of simplification, consider a representative sample of the population composed of one cock, a number of hens equal to the average number of hens per cock in the population, and the young birds produced by those hens.

Mathematically the relationship between sex ratios of adults and the total flock could be expressed by two formulas:

$$(1)\quad h = \frac{H + \frac{1}{2}HP}{1 + \frac{1}{2}HP}$$

$$(2)\quad P = \frac{2(H - h)}{Hh - H}$$

h is the number of hens per cock (young + adult) in the fall
H is the number of adult hens per adult cock
P is the number of young birds per hen

From formula (1) it can be seen that h varies between absolute limits of H and 1. This means that the fall sex ratio can be no more divergent than that of the adults, and that where there is an unequal proportion of adult hens and cocks the fall sex ratio can never quite reach equality. Furthermore, where the adult sex ratio is near equality, there can be but slight variation in the fall ratio and errors of field observation would outweigh variations in fall sex ratio. Thus with a balanced adult sex ratio the formula would be of no practical value.

In parts of the Midwest and East, where among adults there may be as many as six or seven hens per cock, formula (2) could serve as a useful check on field data. For example, on Pelee Island in the fall of 1948, Stokes (1948) estimated about seven hens per cock. Production that year as computed from bag checks was about six young per hen. From formula (1) we can compute that there would have been 1.27 hens per cock in the fall. If, however, production had been only two young per hen, a production higher than that found in South Dakota in 1945 (Kimball, 1948), then there would have been 1.75 hens per cock.

Variations as great as indicated above might well be within limits detectable by careful field observations. Thus, if the investigator could be sure that the fall ratio were somewhere between 1.2 and 1.3 hens per cock when the summer sex ratio had been strongly out of balance (6 or 8 hens per cock), then he would know that the production of young birds for that season was high. Regardless of the adult sex ratio a fall ratio of more than 1.5 hens per cock indicates low production.

Sex Ratio and the Bag Check: The technique of estimating production from the proportion of young to old birds in the bag has become standard for several species. While a few phases of this method still contain unknowns, such as differential rates of kill for young and old birds and reliability of aging techniques, the greatest problem in pheasants is the interpretation of results in terms of production per hen.

Since the number of young cocks in the population is a function of the number of adult hens rather than cocks, and since the ratio of hens to cocks varies from near equality to as much as 8 or

10 to one, then the same rate of production per hen might result in widely different young-to-old ratios in cocks. This was discussed by Kimball (1948) and Petrides (1949) and is generally recognized by technicians, yet it may be overlooked when two areas in the same state are compared.

The importance of sex ratios in this connection is well illustrated in comparing areas such as the Prairie Farm and Rose Lake Wildlife Experiment Station, both in Michigan. Age ratios of cocks were studied in bag checks at both places in the three years 1940–42. The average ratio during this period at the Prairie Farm was 18.5 young per adult cock, while that for Rose Lake was 12.3 young per adult (Allen, 1947). During the same years, Shick (1947) made an intensive study of populations on the Prairie Farm and found spring sex ratio to average about 14 cocks: 100 hens. The Rose Lake sex ratio is known only approximately, but was believed to vary from about 20 to 25 cocks:100 hens during the three winters.

Although we have only rough figures for calculating production per hen, they will serve for purpose of illustration. At Rose Lake about 4.5 hens per cock produced 12.3 young cocks, or an average of about 2-3/4 young cocks per hen. If they produced the same number of young hens, the average production per hen at Rose Lake was a little more than 5 young birds.

At the Prairie Farm 7.14 hens per cock produced 18.5 young cocks per adult cock, or 2.59 each. Production at the Prairie Farm must have been about 5.18 young per hen. Thus, from the rough figures at hand, it would appear that average production at Rose Lake was about the same as at the Prairie Farm. More reliable sex ratios would be necessary to test this point.

Problems in Observing Sex Ratios: Undoubtedly, failure to utilize sex ratios to a greater extent in population studies stems from the difficulty with which reliable figures are obtained. In most states technical personnel is scarce, and wildlife problems needing attention are always beyond the physical limitations of the staff assigned to them. Consequently it has seemed expedient in many instances to use qualified men in planning surveys and interpreting results, and to rely on unskilled or semiskilled help for making detailed observations.

Linduska (1947) pointed out some of the variables in observed sex ratios during winter and early spring in Michigan. He cited roadside counts made by conservation officers in a total of more than 107,000 miles of driving between February 1 and April 15, 1946. The ratio of hens to cocks seen in early February was 6.1 to 1. In the last half of the month it increased to 7.3 to 1, after which there was a steady decline in proportion of hens. By early April, the observed ratio was 2.1 to 1. Results of roadside counts over 15,699 miles during a week of the following December indicated a ratio of 3.6 hens per cock.

To some extent changes in observed sex ratios may indicate changes in the actual proportion of hens to cocks in the field. Buss (1946) noted the gradual decline in proportion of hens to cocks over winter, and implied that this might result from differential mortality of hens. Large shifts in observed ratios over two or three months, such as those noted in the Michigan study, however, seem

likely to be the result of differences in behavior of the birds or conditions for observations.

Buss (*op. cit.*) found wide differences in observed sex ratios obtained by different methods. Although the average sex ratio from feeding stations was similar to that obtained by field workers in connection with other work (22:100, as compared with 20.8:100), results for one or two individual counties differed considerably. Furthermore, there was a wide difference between sex ratios observed in the field and those obtained from winter trapping records, but it is not known whether trapping is more or less representative than sight observations. Although some of these differences might have resulted from inadequacies in the samples, it appears that a large part comes from variations in techniques.

Janson (1946) reports that the time of day is important in making sex ratio counts during the spring months. In South Dakota, from mid-April to the end of June, he found hens and cocks to be about equally abundant along roadsides between the hours of 6 and 7 a.m. (where the actual ratio was believed to be about one to one). In mid-day, however, hens were less in evidence.

From this observation it seems that sex-ratio counts might be made with fair accuracy in early morning counts, but it is difficult to find volunteer co-operators who are abroad at this time. Evening counts were found to be better than those taken at mid-day, but gave lower results for hens than morning counts.

Numerous workers have commented on the difficulty of obtaining reliable winter sex-ratio counts when cocks and hens are likely to be in separate flocks. Kimball (1949) believes that the most reliable way of estimating the proportion of hens to cocks is by flushing pheasants from concentration areas in severe weather. This method would be most applicable in areas like South Dakota, where severity of weather and scarcity of woody cover bring about greater concentrations of birds in favorable areas than in pheasant ranges further east.

Allen (1942) used the proportion of cocks to hens flushed by hunters on the opening day of the hunting season as a measure of prehunting season sex ratio. This, as he recognized, seemed to give an unrealistic ratio (132♂♂:100♀♀). Either the cocks flushed at a higher rate than hens, or there were unusual concentrations of cocks in the areas hunted, since the adult population at Rose Lake had an excess of hens. As we have seen, it would be impossible to have more cocks than hens in the fall population unless some as yet unrecognized factors operate to greatly reduce the number of hens.

In this same study, it was found that cocks flushed in greater proportion than their relative numbers would warrant until late winter, and Allen believes that reliable sex ratios cannot be obtained by this method before January.

A similar situation was observed in the Lancaster Valley, Pennsylvania, in two morning and evening roadside counts in September, 1951. In this area, where summer observations indicated an adult ratio of 8 or 10 hens per cock, these two September counts gave totals of 80 cocks and 48 hens. It was apparent that flocks of birds seen did not represent individual broods and that the

cocks were flocking together, but the reason for the appearance of such a marked excess of cocks is not clear.

A positive method of determining fall adult sex-ratios is available in areas where shooting of both sexes is permitted. The technician can estimate the proportion of young to adult for both sexes by means of bag checks, and since the two proportions bear a relationship to each other determined by the sex ratio of the adults, it is a relatively simple matter to compute the fall sex ratio of the adults (Kimball, 1948), assuming that any greater vulnerability of young birds will have the same effect on the two sexes.

Thus, if the age ratio of cocks, expressed as young to adult, be divided by the age ratio of hens, the quotient will be the sex ratio of the adults in terms of hens to cocks.

There are few places where this method would be applicable, since hens are not legal game in most states. Nevertheless, the importance of evaluating sex-ratio techniques is sufficient to warrant intensive studies wherever the opportunity is afforded. If we could be sure of the true ratio at any period, then it might be possible to compare observed ratios at different seasons to this standard and arrive at some sort of correction factors so as to make observed ratios obtained by extensive methods more usable.

Unfortunately, there seems to be a belief in many quarters that projects designed to test methods fall into the category of "fundamental" research, and that such projects would be a waste of sportsmen's funds. To the contrary, in view of the many surveys designed to evaluate populations, any improvement of accuracy that will make the results of extensive investigations by untrained personnel more reliable is in the interest of economy.

Population studies have done much to remove guesswork from game management, but the most important bottleneck to full use of field observations is the poor reliability of sex-ratio data.

SUMMARY

Sex ratios are of primary importance in interpretation of extensive studies of pheasant populations. They are necessary for converting crowing-cock indices to population estimates even where annual trends are to be studied in the same area.

Reliability of population estimates from hunting season kill of pheasants suffers primarily from inability to estimate sex ratios accurately.

Fall sex ratio is an index to production and where adult sex ratios are divergent can serve as a good check on production per hen.

Age ratios of cocks cannot be interpreted directly as an index of productivity, even within the boundaries of one state, unless adult sex ratios are known.

The relationship between observed and actual sex ratio varies significantly from season to season and according to the method of observation.

In view of their importance in population studies and the lack of reliability of present methods, it is believed that intensive studies on techniques for obtaining sex ratios are a major need in pheasant research.

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TRICHOMONIASIS IN ALABAMA MOURNING DOVES

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The die-off of any wild species in an area usually goes unnoticed or at least unrecorded for some time because sick animals or birds commonly seek secluded places in which to die. Furthermore, people who find dead individuals frequently fail to attach any importance to their discovery and consequently do not report the facts to the proper authorities.

The sudden attack of a disease in Alabama's mourning dove (*Zenaidura macroura L.*) population in the spring of 1950 proved no exception to this rule. Although subsequent information indicates that the die-off in certain counties started as early as January and February, it was not until late April that the fact was reported to game authorities of the Alabama Department of Conservation. Newspaper publicity, coupled with coordinated efforts of a number of interested individuals, resulted in the discovery of a major outbreak of disease in the dove population of the state. Subsequent information indicates that a similar die-off in doves occurred in the entire Southeast (Stabler and Herman, 1951).

The first reported major outbreak of disease in mourning doves in Alabama occurred in Autauga County, in central Alabama, in March, 1950. The Agricultural Agent of that county, however, reports that some doves died as early as January, 1950. Most of this mortality was reported from hog feeding lots between Autaugaville and Prattville. One farmer at Autaugaville stated that he buried 53 doves at one time in his cattle feeding lot.

Subsequent reports of losses were received from Morgan County in the northern and from Etowah County in the northeast sections of the state in late May, 1950.

The first positive diagnosis of the cause of the disease was made by Carlton Herman, Wildlife Pathologist of the U.S. Fish and Wildlife Service, who identified a protozoan (*Trichomonas gallinae*) from a dove collected at Decatur, Morgan County, Alabama, in late May. Four additional birds (3 adult and 1 juvenile) were submitted to Dr. Herman from Chambers County on June 1. Each of these was found to be suffering from trichomoniasis. The disease was reported from a rapidly increasing number of localities until December, when it was known from 43 of Alabama's 67 counties. The localities reporting a mortality were scattered over the entire State.

On the basis of replies to a questionnaire sent to County Agricultural Agents and Soil Conservation Service employees, most of the loss occurred during June, July, and August. There is no significant indication that there was a sectional difference in the trend of the mortality in the state. It is believed, however, that the peak of the mortality

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in Autauga County, where it was first discovered, probably occurred sometime in April, at a time when doves were still concentrated in flocks. It is of significance that the main die-off occurred after the spring migration, or during the season when the birds affected should be nesting.

AGE RATIOS OF BIRDS AFFECTED

Between May 24 and September 27, 1950, the age of 30 birds suffering from trichomoniasis was determined. Of this number, only three (10%) still had juvenile wing coverts. This percentage of young is much lower than would normally be expected in the population at this season of the year. In North Carolina in 1940, 36% of 170 birds shot in June, July, August, and September were juvenile (Quay, 1951). The low percentage of young among the birds found to have died from trichomoniasis may be due to one of several things: (1) the young may not have been as susceptible to trichomoniasis; (2) more likely the young died in the nest and therefore were not found; (3) possibly breeding was curtailed in birds that recovered from an attack of trichomoniasis. The latter possibility seems most probable as not one of the 12 females dying from trichomoniasis during the normal nesting season showed any signs of egg development. The testes of several males recovered in the 1950 breeding season were less than 9 mm. in length which is considered as the minimum size for testes in breeding condition (Pearson, personal communication). Only two of 10 adult sick males examined were found with testes more than 9 mm. in length while each of the four healthy specimens examined had one or both testes 10.5 mm. or longer (Table 1). The testes of sick birds in addition to being very small for adult birds at that season were somewhat flabby as if they had receded in size. Evidence from seven adult male birds which died from trichomoniasis between March 20 and April 23, 1951, indicates that four of the birds had testes large enough to be considered in breeding condition. These are indications that need further study before any definite conclusions can be drawn.

TABLE 1.—RELATIVE SIZE OF TESTES FROM MOURNING DOVES SUFFERING FROM TRICHOMONIASIS AS COMPARED TO TESTES FROM HEALTHY SPECIMENS

Autopsy No.	Date	Length of Testes Left	Right
Doves Suffering from Trichomoniasis			
184 Ad.	5–24–50	8	7.9
185 Ad.	5–26–50	8	8.5
188 Ad.	5–31–50	7	6.6
200 Ad.	6–15–50	9.5	9
201 Ad.	6–15–50	6.5	6.5
202 Juv.	6–19–50	5.4	..
220 Ad.	6–23–50	8.4	8.4
221 Ad.	6–24–50	6	5.5
231 Ad.	7–20–50	11.7	10.5
238 Juv.	8–4–50	6.1	5.9
241 Ad.	9–15–50	5.3	6.3
242 Ad.	9–16–50	7.9	8.9
Doves Collected and which appeared normal			
187 Ad.	7–1–50	13.0	13.0
189 Ad.	6–2–50	14.5	13.7
190 Ad.	6–2–50	12.5	10.5
143 Ad.	3–29–50	13.5	13.9

Two records on the effect of trichomoniasis on nesting of doves are available, both in Morgan County (northern Alabama). On July 9, 1950, Paul Bryan, T.V.A. Biologist, found two starved young in a nest near which was found a dead adult dove. Tom Atkeson, U.S. Fish and Wildlife Service Biologist, of the Wheeler Wildlife Refuge, reported the finding of two dead fledgling doves on a nest. This evidence is only circum-

stantial but is recorded for what it may be worth.

WEIGHT CHANGES IN SICK DOVES

Doves which died from trichomoniasis were found to be extremely emaciated, and flight muscles on the breast had degenerated until the keel of the breast bone became very prominent (Fig. 1).

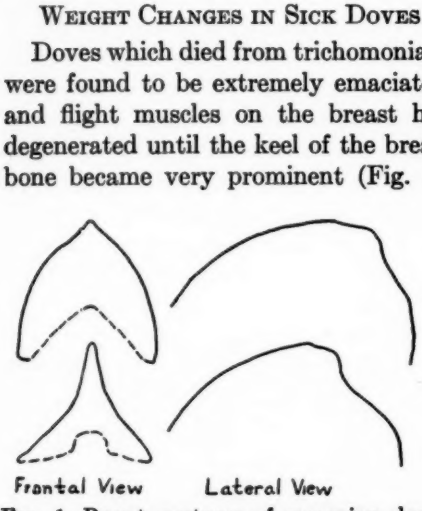

FIG. 1. Breast contours of mourning doves. Top views of healthy bird, bottom views from extremely emaciated dove with trichomoniasis.

Whereas the average weight of healthy doves is about 125 grams (Moore and Pearson, 1941), the average weight of 21 adult doves suffering from trichomoniasis was only 82.3 grams, indicating a weight loss of 34%. The range in weights of sick adult birds autopsied ranged from 61 to 107 grams (Table 2). Some of the birds had died from the disease, some were caught by hand because of their weakened condition, one was shot and two were live-trapped. It is probable that the birds taken alive would have lost additional weight if they had been allowed to live until killed by trichomoniasis. It is also possible that some of the sick birds might have recovered. This, however, seems improbable because of the large lesions involved.

TABLE 2.—WEIGHTS OF ADULT MOURNING DOVES AFFLICTED WITH TRICHOMONIASIS

FEMALES		MALES	
Autopsy No.	Weight	Autopsy No.	Weight
194	85.5	184	82
195	100.2	185	89
198	67.0	188	74
199	85	200	82
224	76	201	73
225	64.5	220	88.5
226	101.9	221	61
227	70.8	231	88.5
233	75.7	241	107
237	76.5	242	74.5
243	106		
AVERAGE	82.6	AVERAGE	81.9

From the size of the swellings in the throat, some of which completely blocked the esophageal passage, it appears that it would be impossible for the afflicted doves to swallow food (Plate 5). A difficulty in eating is further indicated by the fact that dead birds were commonly found carrying a kernel of corn or several weed seeds in their beaks. Seventeen pokeberry seeds were found immediately anterior to the swelling in the pharynx of a dove (Autopsy No. 242) with a caseous mass 25 x 15 x 12 mm. in size. The yellowish, cheesy looking growth weighed 2.8 gms. and had a volume of 4 cc.

It is possible that the final cause of death of birds with trichomoniasis might be starvation resulting from the blocking of the esophagus. One bird, (Autopsy No. 233) which weighed only 75.7 gms. when found dead, however, had no visible lesions or caseous swellings, although live trichomonads were recovered from its throat. This indicates that death may occur even in the absence of caseous swellings which obstruct the food passage. There is a possibility that this bird may have been a carrier which was recovering from an attack of trichomoniasis and that it died of another cause. The bird, however, showed no signs of injury.

NO CARRIERS FOUND IN HUNTING SEASON

Each of 37 doves examined microscopically that were shot in Lee and Tallapoosa Counties during the open season between December 18 and January 13 were negative for trichomoniasis. However, doves with trichomoniasis had been reported from each of these counties earlier in the year. Earlier losses in each of the counties are believed to have been light.

Examination for trichomoniasis was made by means of smears prepared from scrapings from the pharyngeal cavity of the birds. Some smears were made within an hour after the bird was killed. In other cases, however, the examination could not be made until 6 or 7 hours after death. Each slide preparation was searched thoroughly for trichomonads but none could be found. No stains or vital dyes were used on the smears. In fresh materials where the trichomonads are mobile, the identification of the organisms is relatively easy.

Where hunters were contacted in the field it was found convenient to sever the head of the dove at the shoulders and to bring only the heads into the laboratory for detailed examination.

Although no carriers were found in the birds examined it is known that some individuals with trichomoniasis recovered. David Hulse of Decatur, who was live-trapping doves for the Alabama Department of Conservation, captured a bird with yellowish throat lesions on March 23, 1950. When retaken two days later it could barely fly. The bird looked normal when retaken on April 15, 20 days later. On September 16 Hulse wrote to the author as follows: "An occasional bird is still trapped which shows scar tissue on the skin about the base of the lower mandible and more rarely in the lower throat region. These scars sometimes encircle clean openings up to 3/16″ diameter through the skin and into the throat. I would say that these scars might well be the result of trichomoniasis. Of some fifty doves trapped since August 6, about 8 or 9 have shown such scars." None of these birds was examined microscopically but it is probable that several if not all were carriers after recovering from the attack of trichomoniasis from which they apparently had suffered.

APPARENT EFFECT ON POPULATION

General reports on the fall and winter dove population in Alabama are conflicting. However, there is little doubt but that a significant decrease in numbers did occur. By means of a questionnaire, the County Agricultural Agents and Soil Conservation employees in each county were canvassed for their observations on how the December, 1950 dove population compared with that of a year previous. One-half (27) of the correspondents replied that the dove population had decreased, while 31% (17) reported the number unchanged, and 19% (10) indicated an increase.

Hunting success in Lee County, Alabama and vicinity was notably poor in 1950. Records at the Piedmont Agricultural Substation in Tallapoosa County shows that it took 2.2 hours to bag a dove as compared to 0.59 gun hours per dove in 1949. General observations by Research Unit biologists likewise indicated a decrease in the dove population on the Substation area.

A survey of the opinions of Game Wardens in the State by the Alabama Department of Conservation in March, 1951, indicated that 40 counties at that time had fewer doves while 27 still had a population equal to that of a year earlier, March 1950.

It is difficult to secure accurate data on the number of doves that actually died in the 1950 outbreak of trichomoniasis in Alabama. However, the loss must have been great, as 43 of the State's 67 counties were reported to have suffered some mortality. One cooperator estimated the number of dead in his vicinity alone at 4,000 doves. Some correspondents quoted their loss in percentages which ran as high as 25% of the county population. Hulse, as already cited, found that 8 or 9 birds out of roughly 50 doves trapped in Morgan County between August 6 and September 16 showed evidence of having had trichomoniasis. This indicates that at least 16% of the birds trapped had suffered from what appeared to have been trichomoniasis. If this many survived where large losses were reported, then a considerable portion of the population, must have been infected. One cooperator, undoubtedly too pessimistic, replied that all the doves in his county died. In two cases the mortality was reported to be county-wide in distribution.

OUTLOOK FOR FUTURE

It is apparent now that the die-off in doves in Alabama continued to some extent throughout the winter of 1950–51. The deaths during winter, however, were comparatively few in number. Starting in late March, 1951, however, the number of deaths again increased in scattered sections of the State. At the time of preparing this manuscript in June, it appears that the 1951 die-off may become at least as serious, if not worse than it was a year ago.

It is believed that if the current trend of mortality of doves from trichomoniasis continues for another year, the effect of the disease will become serious. Already there is ample cause for alarm. History shows that in the fall of 1881, millions of passenger pigeons blackened the skies in Colbert County, Alabama (Howell, 1928). The immense flocks were seen passing every evening and morning to and from their roosting place near Courtland in neighboring Lawrence County. No more passenger pigeons were reported from Colbert County after that fall. The roosting site of the passenger pigeon at Courtland is in the Tennessee River Valley adjacent to Limestone and Morgan Counties where the mourning dove population suffered a severe loss from trichomoniasis in 1950. An increasing number of biologists and sportsmen are beginning to wonder if a similar disease could have been responsible for the rapid disappearance of the passenger pigeon!

ACKNOWLEDGMENTS

Without the unselfish help of a number of organizations and individuals, it would have been impossible to secure the information presented on the die-off in the mourning dove in Alabama. Significant contributions were made by Carlton Herman, Game Pathologist, and Tom Atkeson, Biologist, both of the U.S. Fish and Wildlife Service; by Jim Keeler and Ralph Allen of the Alabama Department of Conservation; Charles S. Roberts of the State Veteri-

PLATE 5. Mourning dove with extensive trichomoniasis lesions in pharyngeal region. The cankerous growths in doves usually develop at this site

nary Diagnostic Laboratory; Leonard Reid Davis, Parasitologist, U.S.D.A. Regional Animal Disease Laboratory; Samuel A. Edgar, Poultry Pathologist, Alabama Polytechnic Institute Poultry Department; David Hulse, Decatur, Alabama; Robert Stabler, Colorado College; and various field employees of the T.V.A., U.S. Soil Conservation Service, Alabama Polytechnic Institute Extension Service and the Alabama Department of Conservation. The author wishes to express his sincere thanks to each of those who cooperated and helped make the study possible.

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HETEROGENEITY OF TRAP RESPONSE IN A POPULATION OF HOUSE MICE[1]

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Field ecologists seldom find themselves in the confident position of being able to design and carry out sampling programs that are simultaneously in accord with the rules in statistics textbooks and with the limitations imposed by the physical crudeness of many field techniques. Yet wherever conclusions about large populations have to be stated in terms of the attributes of small samples, even the ecologist is committed to the necessity of proving or assuming that there are certain relations existing between his samples and the universe they represent. One such relation has to do with the choice of individuals making up the sample. In general, if all individuals in the population have the same chance of being selected for the sample, it is said to be unbiased or representative, and will form a reliable basis for statistically derived statements about the popula-

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tion. This is not always true if the sampling procedure has the effect of increasing or decreasing the probabilities that certain particular individuals in the population will appear in the samples.

Biased samples may be very common in situations where the choice of their members is not entirely in the hands of the investigator, a frequent difficulty in population studies of small mammals, where sampling is accomplished by trapping, and where there is a strong possibility that not all members of a population will react the same in the presence of a trap.

Variability among the members of a population in their responses to traps may be inherent and thus affect the probability of initial capture, or it may result from previous experience with traps. In either case, allowances will have to be made for such variability in using trapping data to construct quantitative hypotheses about the population. For example, all of the formulas now used for estimating population size from capture-mark-recapture data, both in the original form of Petersen (1896) and Lincoln (1930) as well as in the later modifications of Schnabel (1938), Fisher and Ford (1947), Jackson (1948) and Schumacher and Eschmeyer (1943) depend upon the assumptions that a) all individuals in the population have the same probability of being captured the first time, and that b) this probability remains unchanged after the first capture and with successive recaptures. If some individuals are captured more easily than others, the marked fraction of the population will contain a larger proportion of susceptible individuals than the population at large and so will subsequent recapture samples, leading to underestimation of population size, and so on.

This paper is concerned only with heterogeneity in trap response in a population of house mice, and does not attempt to exhaust the subject of the validity of all estimates of population size. A complete discussion would have to deal with certain other assumptions that are involved, *e.g.* those regarding mortality, natality, movement, *etc.*, and these factors have been eliminated deliberately from consideration here.

DESCRIPTION OF POPULATIONS AND COLLECTION OF DATA

All data used were gathered during a program of live-trapping in two populations of house mice (*Mus musculus* L.) living as natural infestations in buildings at Madison, Wisconsin. Both populations inhabited essentially the same kind of environment, *viz.* heated buildings with an ample supply of food (stored grain), water and cover. Since there appeared to be no differences in the trap reactions of these two populations, they have been treated as one and their records have been pooled for all computations (but see below). The period of study extended from September 28, 1948 to May 27, 1949.

Mice were caught in a fixed number of live-traps operated for three consecutive nights each week, followed by a four-day rest period. Each mouse, at its original capture, was marked with an individual pattern of toe-clippings and then released. A record was made of every subsequent recapture. The termination of any mouse's exposure to trapping was indicated either by its being found dead in the course of the study,

or by its capture during an extensive snap-trapping program at the conclusion. Mice not finally recovered in either of these ways were treated as residents of the population only through the dates on which they last appeared in live-traps. The interpretation of all recapture records in terms of exposure to trapping effort has made it possible to eliminate some of the effects of mortality and migration that commonly complicate such studies of natural populations. Examination of local movements in these same populations demonstrated that there were essentially no irregular wandering movements and shifts of base that might have affected calculations of exposure to trapping (Young, Strecker and Emlen, 1950).

FREQUENCY OF RECAPTURE

If the relationship between the live-traps and the population of mice is such that the probability of being captured on any particular night is the same for all members of the population, then the resulting series of trapped samples would customarily be termed "random", would provide data usable in the estimation of population size and would have certain recognizable statistical characteristics. In particular, if the probability of capture for an individual were small, the frequencies of mice recaptured 0, 1, 2, 3, . . . times in a group uniformly exposed to trapping should be distributed according to the Poisson series.

A preliminary comparison with this model is made by using the records from a sample of 308 mice that were exposed to at least ten nights of trapping. Fig. 1 shows the distribution of recaptures in this group. Since not all of these individuals were exposed to the same trapping effort the abcissa gives number of recaptures relative to the number of nights exposed, *i.e.* number of recaptures per ten nights of trapping. Values for individual specimens are not weighted according to the total trapping effort to which each was exposed, (which would have been desirable for a more exact treatment of the data, since a longer trapping period is essentially a sample of wider scope); an additional minor error is introduced by rounding relative values to the nearest whole recapture.

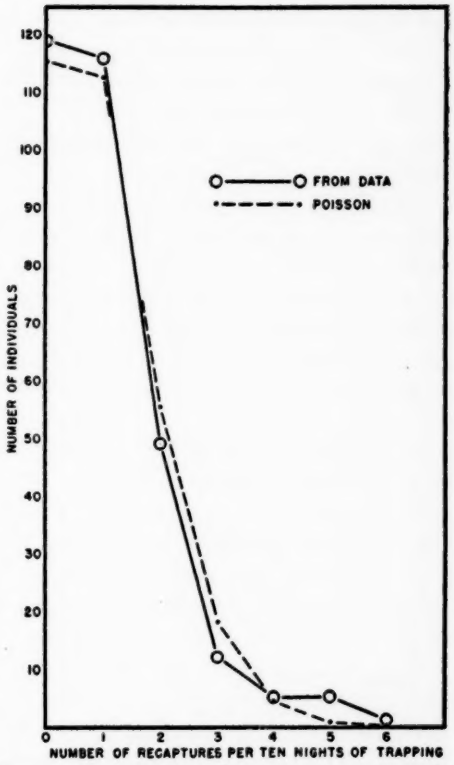

FIG. 1. Distribution of recaptures among all mice exposed to at least ten nights of trapping compared with the expected Poisson Distribution.

Comparison of the resulting curve with the Poisson distribution of identi-

cal mean (also plotted in Fig. 1) indicates a rather poor fit (the probability of grouped X^2 is 0.04). The trapping data contain too many members in the extremely frequent and extremely infrequent recapture classes.

The appropriateness of graduating data in this form to a discontinuous distribution like the Poisson series may be questioned. The same procedure can be used exactly, however, if the data are rearranged somewhat, as described below.

FREQUENCY OF RECAPTURE IN HOMOGENEOUS GROUPS

When the entire population is divided into groups containing only individuals exposed to the same trapping effort, a direct comparison with the Poisson series may be made within each group, and the difficulties of combining samples of unequal weight avoided. This is best accomplished here by separating out groups of mice known to have survived through successive periods of ten nights of trapping following the date of their original capture, and considering the frequencies of recapture within each of these periods. Arranging the data in this way has the additional advantage of emphasizing any tendencies for the pattern of trap reaction to change with the lapse of time. Distributions of recaptures within such periods are shown in Fig. 2. The decrease in area under successive curves is due to mortality or disappearance following the date of original capture, and to the reduction in available time to be recaptured for mice first caught late in the study.

For each of these curves, one should again expect correspondence to a Poisson series if the probability of capture is uniformly distributed over all members of the population. Poisson series of identical mean have been superimposed on the distributions for the first three periods (samples containing more than 100 individuals). Here the correspondence is extremely poor; the samples clearly have too many individuals at either end of the distributions. Values of X^2 and their probabilities for these three comparisons are given in Table 1.

TABLE 1.—COMPARISON OF RECAPTURE DISTRIBUTIONS FOR SUCCESSIVE TEN-NIGHT PERIODS WITH CORRESPONDING POISSON SERIES (cf. Fig. 2)

Period	Number of individuals surviving throughout	X^2	P
Nights 1–10	439	47.064	<0.001
" 11–20	249	32.376	<0.001
" 21–30	155	14.447	<0.002

There does not appear to be any substantial change in the form of the recapture distributions with the lapse of time, indicating perhaps that the tendency toward trap addiction or avoidance is a relatively permanent characteristic of any one mouse. An attempt has been made to compare successive distributions in this respect by computing the fraction of each sample appearing in the zero class (containing individuals not recaptured during the period in question). These fractions have been included in Fig. 2; their confidence limits are obtained from the charts of Clopper and Pearson (1934) under the assumption that their sample values are members of a binomial universe. In spite of the apparent trend through the first five periods, there does not seem to be any reason for supposing that the differences in the sample distributions are real.

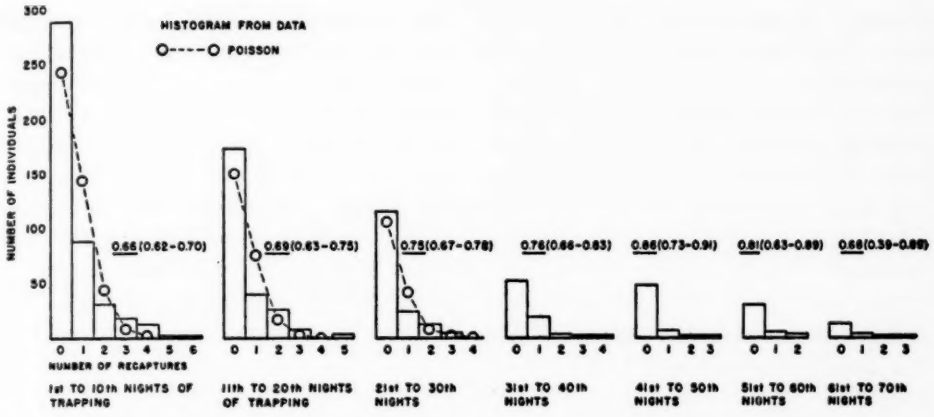

FIG. 2. Distributions of recaptures within groups of mice uniformly exposed to trapping. Underscored numbers are fractions of each group falling in the zero class; numbers in brackets are their 0.95 binomial confidence limits.

The conclusion that reaction to traps does not change with continued experience can be supported further. If the entire sojourn of a group of mice in the trapped population be divided into several sub-periods, and a recapture frequency distribution obtained for each of these, then any tendency for mice to "learn" trap reaction with continually increasing experience with traps should be reflected in changes in the form of the recapture distributions from one period to the next. In Table 2, the trapping history of a cohort of 56 mice that survived in the population through at least 50 nights of trapping has been broken down into five periods of ten nights of trapping each. The distributions obtained for each of these periods are remarkably similar to one another, suggesting again that, once supplied with an attitude toward traps, a given mouse does not change in this respect in spite of an accumulation of experiences with traps.

TABLE 2.—DISTRIBUTIONS OF RECAPTURES AS A FUNCTION OF TIME FOR 56 MICE SURVIVING 50 NIGHTS OF TRAPPING

Period	Number of captures within period 0	1	2	3	4	5	Total
Nights 1–10	41	12	2	0	1	0	56
" 11–20	44	9	3	0	0	0	56
" 21–30	44	9	3	0	0	0	56
" 31–40	43	11	1	0	1	0	56
" 41–50	48	6	1	0	1	0	56

EFFECTS OF COMBINING DATA FROM TWO POPULATIONS

In general, the distribution of recaptures in a sample made up by pooling trapping data from two or more separate trapped populations will not correspond to a Poisson series, even though sampling in each of the populations has been perfectly random. In the case where the number of traps and other conditions are such, however, that the probability of capture for any mouse is the same in all populations, the distribution of pooled recapture data can be used as though it were derived from a single population. In the case at hand, it is thus necessary to demonstrate that the apparent contagion of the sampling dis-

tributions is not simply the result of combining data from two separate populations.

In one of the populations, a total of 2,329 mouse-exposures (one mouse exposed to all traps for one night equals one mouse-exposure; two mouse-exposures would equal two mice exposed for one night or one mouse exposed for two nights, etc.) resulted in 133 captures, or 0.057 captures per mouse per night (the number of traps always remaining constant). In the other, 6,617 mouse-exposures resulted in 340 captures, or 0.051 captures per mouse per night. In Table 3, the terms of Poisson series with means 0.57 and 0.51 are compared (units used are again captures per ten nights of trapping). In the third row of the table a new distribution is derived by adding successive corresponding terms of the first two. This is the distribution that would be obtained from a pooled sample containing equal numbers of mice from the two populations; its mean is 0.54. If a new Poisson series is now fitted to this derived distribution, the correspondence is almost perfect (terms of the Poisson are in row 4 of Table 3). In the study itself, however, the first population was represented in the samples by only a third as many individuals as the second. The effect of unequal representation may be simulated by recombining the terms of the first two distributions after weighting the terms of the second by a factor of three. This has been done in row 5 of Table 3; the mean of the second derived distribution is 0.52. Terms of the corresponding Poisson series are in row 6. Again, the agreement is almost perfect, suggesting that in the case of the present study, data from the two populations may safely be combined without introducing artificial errors.

In cases where the probabilities of capture in populations to be combined are strikingly different, or where, though the probabilities are not very different, the numbers contributed to the pooled sample by each of the populations are very different, use of the Poisson series in testing for randomness in the pooled sample should not be expected to yield informative results.

The pooling effect may appear also when the population, though "single" in the spatial sense, contains elements with differing reactions to traps. For example, if through differences in mobility, feeding habits, etc., the two sexes are trapped with variable facility, then even in a spatially discrete population, though the sexes are individually trapped in a perfectly random manner, the com-

TABLE 3.—DISTORTIONS IN RECAPTURE DISTRIBUTIONS FROM POOLED SAMPLES. NUMBERS IN THE TABLE ARE FRACTIONS OF THE TOTAL SAMPLE

Sample Characteristics	Class (number of captures)					
	0	1	2	3	4	5
Population 1, mean 0.57.....	0.5655	0.3223	0.0919	0.0174	0.0025	0.0003
Population 2, mean 0.51.....	0.6005	0.3062	0.0781	0.0133	0.0017	0.0002
Combined 1:1, mean 0.54.....	0.5830	0.3142	0.0850	0.0154	0.0021	0.0002
Poisson, mean 0.54.....	0.5827	0.3147	0.0850	0.0152	0.0021	0.0002
Combined 1:3, mean 0.52.....	0.5918	0.3102	0.0816	0.0143	0.0019	0.0002
Poisson, mean 0.52.....	0.5916	0.3106	0.0815	0.0143	0.0019	0.0002

bined recapture distribution would show distortions when compared with a Poisson series. If the sex of trapped animals is not recorded, this source of error cannot, of course, be separated from the effects of individual variation in trap reaction among individuals of the same sex Since sex differences in trappability are rarely taken into consideration in studies of this kind, the above analyses have been carried through without reference to the sex composition of the trapped samples or to differential responses of the sexes to traps.

Indications of sex difference in trap reaction were to be found in our data, however. Among males, a total of 3,056 mouse-exposures resulted in 230 captures, 0.075 captures per mouse per night. Among females, 5,890 mouse-exposures brought 243 captures, 0.041 per mouse per night. The technique employed in Table 3 is used in Table 4 to determine the effect of dealing with recapture data from a population not classified according to sex, computing first the terms of Poisson series with means 0.75 and 0.41, then combining and fitting a new Poisson to the resulting pooled distribution. Since in the populations of this study, males and females were represented in the samples in almost equal numbers, the terms of the Poisson distributions are not weighted when they are combined. The distortions appearing here are larger than those found above, in keeping with the greater difference between the means of the two distributions; they are not nearly large enough, however, to explain the really substantial discrepancies found in the actual pooled samples (Fig. 2).

INTERVAL BEFORE FIRST CAPTURE

By a slight shift of viewpoint, it is possible to approach the situation without taking total exposure to trapping into consideration. If the total number of traps set out remains essentially constant on each night (as it did in fact), and the probability of capture within a unit length of time is the same for all individuals (leading to a "random" sample as this is defined above), then the length of time elapsing between the initial capture and the first recapture should have an identifiable distribution. In particular, if the probability of capture within a unit length of time be called p, then the proportion of trappable mice caught at least once by the end of the first time unit should be p; by the end of the second, $p(1-p)$; and by the end of the nth, $p(1-p)^{n-1}$, corresponding to the product of the probabilities of eluding capture for the first $n-1$ periods and being caught during the nth. The discontinuous probability distribution generated by the series

$$p, p(1-p), p(1-p)^2, \ldots, p(1-p)^i \quad (1)$$

TABLE 4.—DISTORTIONS IN RECAPTURE DISTRIBUTIONS CAUSED BY SEX DIFFERENCES IN TRAPPABILITY. NUMBERS IN THE TABLE ARE FRACTIONS OF THE TOTAL SAMPLE

Sample Characteristics	Class (number of captures) 0	1	2	3	4	5
males, mean 0.75	0.4724	0.3543	0.1328	0.0332	0.0062	0.0009
females, mean 0.41	0.6646	0.2721	0.0558	0.0076	0.0008	0.0001
Combined 1:1, mean 0.58	0.5685	0.3132	0.0943	0.0204	0.0035	0.0005
Poisson, mean 0.58	0.5599	0.3247	0.0942	0.0182	0.0026	0.0003

is very convenient to use in the present case inasmuch as the partial sum

$$S_n = \sum_{i=1}^{n} p(1-p)^{i-1} \qquad (2)$$

converges to 1 for all admissible values of p $(0 < p \leq 1)$, and estimates of p may be obtained very easily from trapping data dealing with mice that are individually identified. The mean of the distribution is given by

$$\mu = \lim_{n\to\infty} \sum_{i=1}^{n} ip(1-p)^{i-1} = 1/p \qquad (3)$$

It can be shown that $p = 1/\bar{x}$ is a maximum-liklihood estimate of p (where $\bar{x}$ is the mean length of time elapsing between original capture and first recapture in the sampled population). The variance of the distribution is given by

$$\mu_2 = \lim_{n\to\infty} \sum_{i=1}^{n} i^2 p(1-p)^{i-1} = (2-p)/p^2 \qquad (4)$$

Distributions for several values of p are plotted in Fig. 3.

In comparing the actual distribution of time intervals with the foregoing power-series distribution, one does not need to be concerned with the fate of a mouse following its first recapture. He may therefore dispense with correcting data for survival, *etc.*, and use in the computations any mouse that has been retaken at least once after being marked. Similarly, those mice that die or emigrate before being recaptured at all will be distributed pro rata over groups that would have been recaptured after 1, 2, 3, . . . intervals (assuming that tendency to die or emigrate is not related to trap vulnerability), and thus do not introduce a bias for having been omitted from consideration. The distribution will not give good results if insufficient time is allowed in trapping any group of marked mice to recapture at least once almost all trappable members of the group. It will also fail to represent properly a situation in which the number of traps is so small that almost every one of them catches a mouse on every night that it is set. The latter situation is seldom encountered.

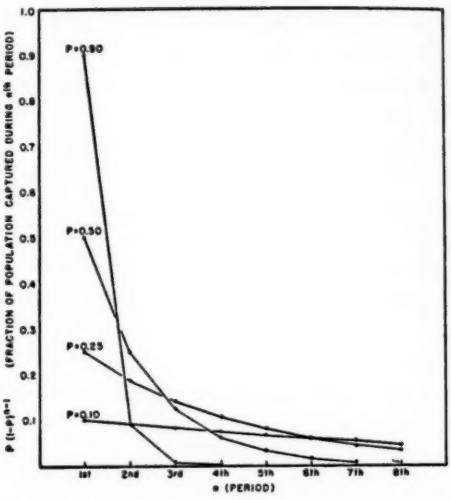

FIG. 3. Distributions of $p(1\text{-}p)^{n-1}$ for several values of p.

Fig. 4 shows the distribution of intervals elapsing between initial capture and first recapture for 721 mice recovered at least once in the study. The value of p computed from this distribution is 0.46; the distribution of $p(1-p)^{n-1}$ is plotted in the same figure for direct comparison with the trapping data. It is quite clear that the series does not provide a good fit to the data ($X^2 = 114.033$, for which the probability is less than 0.0001), and further (by

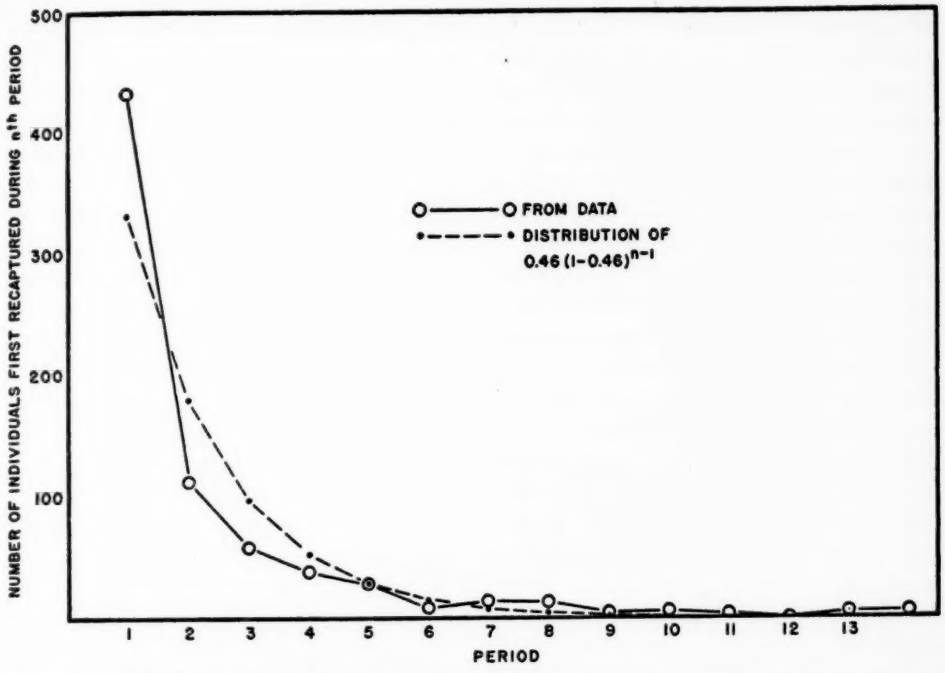

FIG. 4. Distribution of intervals between release and first recapture compared with an expected power-series distribution.

reference to Fig. 3) that the fit could not be improved by adjusting the value of p. The data appear to contain too many individuals recaptured soon after release and too many first recaught after a prolonged interval, qualities that seem to indicate the same kind of heterogeneity found above in the distribution of recapture frequencies.

DISCUSSION

The inferences or conclusions to be drawn from these analyses must be subject to several reservations. Either positive or negative trap reaction may be a trait of a given mouse before it has been captured at all; an unusually curious mouse would perhaps be more vulnerable to a first trapping than one unusually wary of new objects in its environs. It is certainly conceivable, therefore, that any trapping program of this kind is studying only a particular fraction of the population to begin with, only individuals vulnerable enough to be caught at least once. This primary ambiguity is invariably involved whenever one uses the term "population"—the only population available to the investigator is that which is represented in his samples. It is also obvious that the data can describe only an unknown fraction of any one mouse's career, and that therefore very little can be said about innate vulnerability, since all conclusions must be stated in terms of behavior after an initial capture. These conditions, of course, limit any study dealing exclusively with recapture data.

Beyond such considerations, the con-

clusion emerges quite clearly that the samples described above are not random in the ordinary sense of that word, and would lead one into difficulties if they were used for the estimation of population size. It has been shown that the characteristics of these distributions cannot be ascribed to the effects of pooling unlike populations, either those represented by two sexes within a spatially continuous group of animals, or by the inhabitants of two separate buildings. They might be explained by postulating that the populations contained both trap-shy and trap-addicted animals contributing surpluses to either extreme of those sample distributions that could not be matched to Poisson or power-series distributions.

Another explanation might assume that the normal foraging areas of the mice were small in relation to the distances between traps. Under these circumstances, some of the marked mice might be expected to have removed themselves temporarily out of range of any trap and others to have established themselves close to a trap in which they would then be caught very frequently. The previously cited study of local movement in these populations (Young, Strecker and Emlen, 1950) indicated that mice have a tendency to be recaptured in traps from which they were most recently released, also that the average distance moved by mice between successive captures was slightly less than the average distance separating adjacent traps.

It has not been the objective of this paper to provide an explanation for the form of the sampling distributions, but simply to point out that the form of the distributions as they actually occur is not appropriate to the use of the Lincoln index and any other measurements that depend upon unbiased distribution of probability of capture, and to demonstrate a few ways in which this inappropriateness can be detected. Hypotheses relating to the reasons for the inability of live-traps to sample a population randomly must be investigated by independent means. If, for example, the distribution of the traps in relation to the movements of the mice is responsible for the difficulties encountered, it should be possible to establish this by changing the locations of the traps in a random manner throughout the study, and noting the effect on the sample distributions. Hypotheses relating to innate trap vulnerability would be more difficult to examine experimentally.

It does not seem unjustified to conclude that the arbitrary application of the Lincoln index or any method based on the same principle to live-trap studies in general without at least a nod in the direction of evaluating distortions due to trap-reaction leaves such latitude for experimental error that estimations of population size made by this method can seldom be viewed with any degree of confidence. It would appear to be the responsibility of those investigators who use recapture data to supply themselves with concrete evidence that the samples gathered in any study conform to the assumptions made when various methods of computing population size were invented. It should be noted here that the assignment of confidence limits to recapture sample values (described recently by Adams, 1951, and originally by Ricker, 1937) does not solve the problem of biased distribution of sampling effort.

It is possible that continued investigation of peculiarities like trap-habit in a quantitative way will result eventually in the development of methods for normalizing crude recapture data showing various kinds of irregularity. In the present case, this would require a closer examination of, say, the departure of recorded recapture frequencies from the expected distributions, taking sign as well as magnitude of deviations into consideration. It could be shown that the consistent form of the departures from expectation found here, considering both sign and magnitude of the discrepancies in the various frequency classes, is highly improbable. The writers hope to take up this matter in a later communication.

SUMMARY

1. Capture records from two live-trapped natural populations of house mice have been examined for evidence of unequal distribution of trapping effort among members of the populations.
2. Distributions of recapture frequencies in pooled data from the populations showed large deviations from the Poisson series. Such deviations may arise as a result of combining data from separate populations or as a result of differences in reaction to traps in the two sexes within a single population. These factors are discussed, but found to be incapable of producing the observed deviations.
3. Distribution of time intervals elapsing between original capture and first recapture showed similar deviations when compared with an expected power-series distribution.
4. The form of the sample recapture distributions did not show any evidence of a progressive change with time, suggesting that individual variation in trap reaction is not a function of experience with traps.
5. These results suggest that live-trap samples of the sort used are likely to be strongly biased, and unlikely, therefore, to provide a secure basis on which to construct estimates of population size. Some possible direct causes of biased live-trap samples in the mouse population are discussed, but on the basis of the available information, none of these is chosen as the definitive cause in the case at hand.

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THE FOOD HABITS OF SEVERAL POPULATIONS OF COTTONTAIL RABBITS IN OHIO

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The cottontail rabbit, *Sylvilagus floridanus mearnsi*, is the most important small game mammal in Ohio. Yet, the knowledge of its food habits is uncertain because they have been determined by field observations only. A histological method for the determination of rabbit food habits by analysis of the herbaceous plant particles found in rabbit fecal pellets, (Dusi, 1949), made possible a much more precise record than any compiled previously. Fecal pellet analyses for herbaceous plant content correlated with field observations of woody plant utilization provided a very good index to food habits of this species.

A research program was devised to attain the following objectives:

1. To determine the food habits of several representative populations of cottontail rabbits in Ohio for the period of one year.
2. To correlate these food habits with the variations in land-use on the different study areas.
3. To make management recommendations based on food habits findings.

This research was conducted at the Ohio State University under a research fellowship granted by the Ohio Wildlife Research Unit. Dr. Charles A. Dambach is due much appreciation for his helpful advice. Dr. Eugene H. Dustman and Kenneth Chiavetta collected fecal pellet samples from areas in Wood County and Williams County, respectively, and thus made available data which would not have been obtainable otherwise. In order to accomplish the objectives of this research, the following study areas were used:

1. A main area was located near Blacklick, Franklin County, Ohio, at 279 Waggoner Road. This was situated near enough to the writer's home that it could be visited frequently and intensively studied. Minor fluctuations in the food habits of the rabbits of this area could then be determined. The rabbit population was determined by live trapping and tagging. In relation to the size of the area, the population was approximately one rabbit for every two acres. The rabbits, however, remained concentrated on a much smaller area and represented a population of nine rabbits per acre. This population was protected from hunting and was of adequate size for ease in collecting pellet samples.
2. A second area was located in Southwestern Ohio near Russell, Highland County, Ohio, on the state-owned Oldaker Farm. This area was visited only four times, at intervals spaced so

that samples would indicate any changes of food habits due to seasonal variation of the vegetation. The rabbit population was estimated from the frequency of pellets found in relation to those found on the Franklin County area that had a known population. The population of the Highland County area was approximately one rabbit for every five acres. This low population made it difficult to find pellet samples during summer months because of heavy vegetation.

3. A third area was located in northwestern Ohio, in Wood County near Mermill. Samples from this area were taken only in the spring. The size of the population of rabbits on this area was unknown.
4. A fourth area was also located in northwestern Ohio, in Williams County near Bryan. Collections from this area were so spaced that they did not provide information for the entire year. The population size was unknown.

TECHNIQUES

Fecal pellet samples were used so that the populations would not be altered by the sampling.

Pellets were collected and stored in coin envelopes. Pertinent data were recorded on a form printed on the envelopes. Only freshly dropped pellets were collected. These could be distinguished from old, weathered pellets by a shiny mucous coating.

Pellets were collected from the Franklin County area at intervals of approximately ten days, throughout one year. The number of samples taken each time varied with the abundance of pellets. Usually about five samples were taken.

Samples were collected at four different times from the Highland County area. Collection dates were so spaced as to obtain a range of growth changes in herbaceous plants and to obtain one set of winter feeding samples. On this area, samples were taken of all pellets found.

In addition to collecting fecal pellet samples, specimens were taken of all plants present in sufficient quantity to be food sources. Epidermis of these plant specimens was used for preparing histological reference slides.

Reference slides were prepared by two methods. In the first method, epidermis was stripped from the leaves of the plants and treated by a modification of Blaydes' (1939) schedule. This method provided the most desirable type of slide because the epidermis was in a large strip and was easily located under the microscope. The second method was used for plants whose epidermis could not be removed easily. This method involved the maceration of the leaves until the tissues separated. By teasing the tissues into small particles, sections of epidermis could be separated from other tissues. The disadvantage of this method was that the pieces of epidermis were small and scattered among other tissue particles. Thus they could not be located easily.

The following schedule was used for preparing the stripped-off epidermis mounts.

1. Strip epidermis from freshly collected plants and fix it in 100 per cent ethyl alcohol for ten minutes.
2. Transfer at 3 minute intervals through 95, 70, 50, 30, and 10 per cent alcohol and into distilled water.
3. Stain in phenolic Bismarck brown Y for 10–20 minutes.
4. Rinse in distilled water.
5. Dehydrate at 3 minute intervals in 10, 30, 50, 70, 95 and 100 per cent alcohol.

6. Transfer to oil of wintergreen for 10 minutes.
7. Mount outerside up on a microscope slide using clarite as a mounting medium.

The macerated tissue mounts were prepared by treating the tissues by Jeffrey's methods (Johansen, 1940) according to the following schedule.

1. Cut the material into small slices. Kill and fix it in formalin-aceto-alcohol for at least 18 hours.
2. Wash it in two changes of 50 per cent alcohol.
3. Macerate it in a solution of 10 per cent nitric acid and 10 per cent chromic acid freshly mixed in equal parts. The time required for maceration varied from 4 to 48 hours. Warming the solution helped. Test the material occasionally to determine when the cells begin to separate, removing it before they separate too freely.
4. Wash it thoroughly in tap water.
5. Stain it in phenolic Bismarck brown Y, 6–10 hours.
6. Remove surplus stain by rinsing it in tap water.
7. Dehydrate in 10, 30, 50, 70, 95, and 100 per cent alcohol.
8. Transfer it to oil of wintergreen for 10 minutes.
9. Place a small portion of the material in a drop of clarite on a microscope slide. Carefully break the material into small pieces and mix it with the clarite being careful to avoid creating air bubbles. Then place a cover slip on top.

When reference slides of plant epidermis were prepared, they were analyzed for characteristic structures and were then photomicrographed or copied with a camera lucida. Prints or drawings were mounted in a composite plate showing a general section of a large portion of tissue magnified about 200 times and special structures magnified about 850 times.

Fecal pellets were analyzed by a qualitative sampling procedure and results were treated on a frequency-of-occurrence basis.

In order to do this, a portion of each pellet sampled was first mounted on a microscope slide using the following procedure.

1. Place a small portion of a pellet on a clean microscope slide; add a drop or two of 100 per cent ethyl alcohol and tease it into small particles with a dissecting needle.
2. Add several drops of polyvinyl alcohol mounting medium and mix the particles in it.
3. Place a 3/4 inch square coverslip over the material and flatten it into place. The slide is then ready for examination. This should be done within a few hours or the slide will have to be ringed to prevent air bubbles from entering.

The analysis of a prepared pellet slide was accomplished by placing the slide upon the mechanical stage of a microscope and systematically viewing each particle of the pellet. A magnification of 100 to 150 times was used for the preliminary examination of each particle. If higher powers were desired the high dry objective was used yielding a magnification of 430 to 645 times.

ANALYSIS OF RESULTS

The analyses for the Franklin County area were made from 101 pellet samples,

collected on 27 dates from April 13, 1947, to April 4, 1948. Table 1 is a list of the plants found on the area in enough abundance to be important as prospective foods. Figure 1 shows the data for each collection period presented graphically by mean percentages. In addition to this, field observations which should be correlated with analyses show: on January 19, 1948, when about two inches of snow covered the ground, apple twigs were barked; on January 29, 1948, nine inches of snow were present and apple twigs and poison ivy were utilized; and on February 11, 1948, with 7–8 inches of snow present, honeysuckle was being cut. These were the only snow records and woody plant cutting.

The graphs in Figure 1 illustrate the fluctuations of plant utilization throughout the year. In the case of coarse, rank-growing grasses like orchard grass, timothy, and nodding wild-rye, the graphs show that these are utilized while growth is tender and palatable, but little used when developed and siliceous. Yet, during seasons when other food is scarce, this coarse vegetation is resorted to. The most important line of the graph shows the utilization of bluegrass. This low growing grass was much utilized at all seasons of the year. During snow periods, rabbits dug through the snow and ate bluegrass. During the periods of snow designated, the drop in utilization of bluegrass would seem to be closely correlated with

TABLE 1.—FOOD PLANTS AVAILABLE ON THE FRANKLIN COUNTY AREA

Poa pratensis	Bluegrass
Dactylis glomerata	Orchard Grass
Phleum pratense	Timothy
Triticum aestivum	Wheat
Elymus canadensis	Nodding Wild-rye
Chaetochloa glauca	Yellow Foxtail
Andropogon virginicus	Virginia Beard-grass
Zea mays	Corn
Oxalis stricta	Yellow Wood-sorrel
Rumex crispa	Curled Dock
Rumex acetosella	Sheep Sorrel
Potentilla canadensis	Common Cinquefoil
Rubus allegheniensis	High Blackberry
Amygdalis persica	Peach
Pyrus communis	Pear
Malus malus	Apple
Crataegus ssp.	Thornapple
Melilotus alba	White Sweet-clover
Trifolium repens	White Clover
Vitis ssp.	Wild Grape
Acer negundo	Boxelder
Rhus toxicodendron	Poison Ivy
Ulmus americana	American Elm
Urticastrum divaricatum	Wood Nettle
Plantago major	Common Plantain
Daucus carota	Wild Carrot
Solidago canadensis	Canada Goldenrod
Achillea millefolium	Common Milfoil
Cirsium arvense	Canada Thistle
Chichorium intybus	Chicory

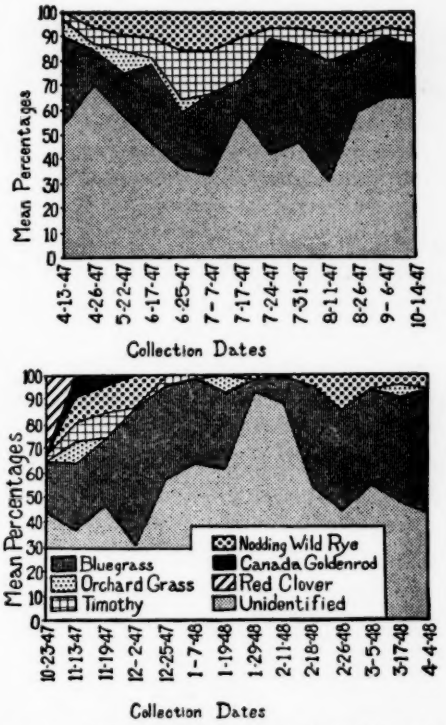

FIG. 1. Graph of the indices of rabbit food habits from the Franklin County area. Data for each collection period are shown by cumulative mean percentages.

the rise of unidentified material. Woody tissues probably make up the greatest portion of the unidentified plants. They are listed as such because woody tissues cannot be positively identified with the analytical method used.

Analyses for the Highland County area were made from 30 pellet samples collected on four dates: April 8, 1947; June 20, 1947; August 28, 1947; and January 21, 1948. Table 2 lists the important food plants which were available. Figure 2 shows graphically the index to food habits obtained by the analyses. Relationships of the plants to the rabbits' food habits were much as among those on the Franklin County area, with the exception that Korean lespedeza was utilized enough to suggest its value as a supplemental food. Field notes show that there was no evidence of cutting on woody plants on the area.

Rabbit food habits on the Wood County area were determined from eleven samples collected on: March 18, 1947; April 8, 1947; and April 17, 1947. This scant information is helpful in providing a food habits index for this period, which is one of food scarcity.

Figure 3 presents the index graphically.

TABLE 2.—FOOD PLANTS AVAILABLE ON THE HIGHLAND COUNTY AREA

Poa pratensis	Bluegrass
Dactylis glomerata	Orchard Grass
Phleum pratense	Timothy
Triticum aestivum	Wheat
Zea mays	Corn
Ailanthus glandulosa	Tree-of-heaven
Rubus allegheniensis	High Blackberry
Gleditsia triachanthos	Honey-locust
Trifolium pratense	Red Clover
Trifolium hybridum	Alsike
Lespedeza stipulacea	Korean Lespedeza
Lespedeza bicolor	Bicolor Lespedeza
Ulmus americana	American Elm
Quercus ssp.	Oaks

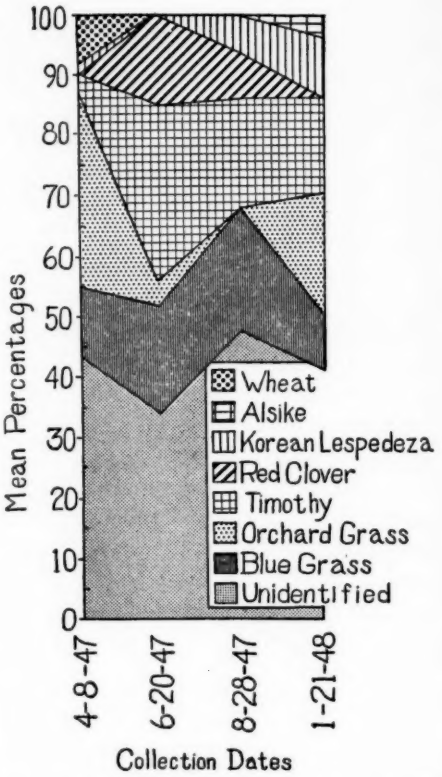

FIG. 2. Graph of the indices of rabbit food habits from the Highland County area. Data for each collection period are shown by cumulative mean percentages.

Much more cutting of woody plants was noted in the field. Cutting on *Crataegus* fruits and honey-locust pods was observed.

Food habits of the rabbits on the Williams County area were determined from 15 pellet samples collected on February 1, 1947; July 16, 1947; August 9, 1947; September 4, 1947; September 15, 1947; and September 20, 1947.

Figure 4 is a graphic index to the foods eaten. Field notes show no utilization of woody plants.

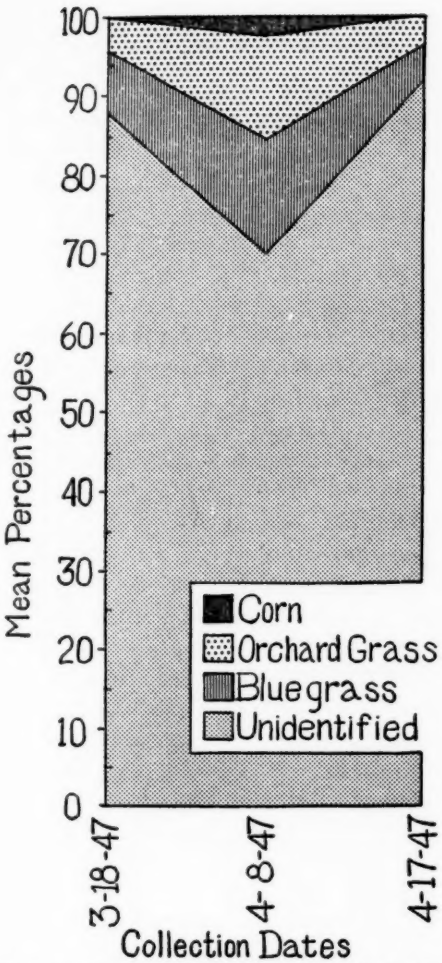

FIG. 3. Graph of the indices of rabbit food habits from the Wood County area. Data for each collection period are shown by cumulative mean percentages.

DISCUSSION

Indices and field notes show that during the period of this study, Ohio cottontail rabbits utilized herbaceous plants almost entirely for food. It was only during periods when snow covered these foods that woody plants were resorted to. This is quite different from results obtained by Dalke and Sime (1941), whose field analyses enabled them to separate the food habits of New England cottontails into three seasonal periods: winter, summer, and fall.

Ohio cottontails utilized grasses to a greater extent than dicots. Among the grasses, bluegrass was the most important. This was probably due to the small amount of seasonal variation in bluegrass growth and development. The more rankly growing grasses were utilized mainly during periods of succulence, or their basal portions fed on during the winter.

Data did not show much variation in food habits as a result of varied land utilization. On the Highland County area, lespedezas could be grown. Here

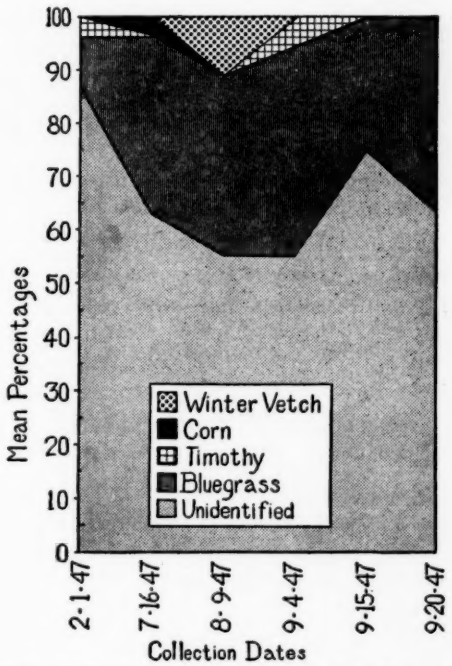

FIG. 4. Graph of the indices of rabbit food habits from the Williams County area. Data for each collection period are shown by cumulative mean percentages.

Korean lespedeza was utilized to a slight degree. There was no similar variation on other areas.

In all of the samples, a high percentage of material was recorded as unidentified. These unidentified particles were mostly conductive and supporting tissues the identity of which cannot be determined by the methods used here. It is believed that these particles were from the plants of which epidermal particles were identified in the samples. During the winter months when the rabbits fed more on herbaceous stems and roots, which have a greater percentage of composition of supporting and conductive tissues, the percentage of unidentified material increased. This seems to bear out the previous suggestion that the unidentified material is part of the same plants as the identified particles.

The variety of common plants utilized as food might indicate that food is not the most important management consideration.

Bluegrass should be recognized as an important food plant.

Plants of seasonal importance were: timothy, orchard-grass, nodding wild rye, Korean lespedeza, and red clover.

SUMMARY

1. A food habits research project was designed to accomplish three objectives:
   a. to determine throughout one year, the food habits of several populations of Ohio cottontails;
   b. to correlate the food habits of these rabbits with any land-use differences which might occur on the collection areas;
   c. and to make wildlife management recommendations in accordance with research findings.
2. Histological analyses were made on 101 fecal pellet samples, collected on an area in Franklin County at approximately ten-day intervals. Thirty pellet samples analyzed were collected from the Highland County area on four dates: April 8, 1947; June 20, 1947; August 28, 1947; and January 21, 1948. Fragments of information were obtained from 11 samples from Wood County and 15 samples from Williams County.
3. Data indicate that the major portion of the rabbits' food was herbaceous plants and that woody plants were utilized during periods when snow covered herbaceous foods. Indices show that bluegrass was an important all season food. Several other grasses, orchard grass, timothy, and nodding wild-rye, were seasonally of value. Red clover and Korean lespedeza were seasonally used dicots.
4. Management recommendations indicate that food is not the foremost problem in maintaining rabbit populations in Ohio. Bluegrass should be well represented in any plantings for rabbit food.

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MOURNING DOVE PRODUCTION IN NORTH DAKOTA SHELTERBELTS, 1950

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Except for studies by McClure (1943 and 1946) and Rosene (1950), little has been done to determine the contribution of the north-central states to the production of the mourning dove, *Zenaidura macroura*. The purpose of this investigation was to determine the production of mourning doves in shelterbelts of east-central North Dakota.

In the 1930's, 18 shelterbelts were planted on 48 sections east, west, and north of the city of Jamestown, North Dakota, as part of the Great Plains shelterbelt plan (Kellogg, 1934). From these, five shelterbelts were chosen as possible good nesting sites for mourning doves, each because of some particular nearby condition or because of an individual characteristic of the shelterbelt. The shelterbelt located on Jamestown College property was near a residential area. Shelterbelts owned by Russell Joos, Hermann Frey, and the County Farm were planted in 1936 and were among the oldest shelterbelts in the area. A second County Farm shelterbelt was near a cemetery which contained many evergreen trees and production between the two areas could be compared.

The dimensions and areas of the shelterbelts were: (1) Joos—41 yards by 880 yards and 7.4 acres, (2) County Farm I—30 yards by 2640 yards and 16.3 acres, (3) County Farm II—30 yards by 880 yards and 5.4 acres, (4) Herman Frey—41 yards by 2530 yards and 21.4 acres, and (5) Jamestown College—30 yards by 840 yards and 5.2 acres. The total acreage of the five shelterbelts was approximately 56 acres, and the total length was 7770 yards, or approximately 4.4 miles. The rows of trees and shrubs in a shelterbelt ranged from 10 to 17. All shelterbelts chosen had attained good growth, with the center rows of Chinese elm, *Ulmus pumila*, and Eastern cottonwood, *Populus deltoides*, reaching a height of about 30 feet. Edge rows of the shelterbelts chiefly consisted on Russian-olive, *Elaeagnus angustifolia*; with chokecherry, *Prunus virginiana*; wild plum, *Prunus americana*; common lilac, *Syringa vulgaris*; honeysuckle, *Lonicera* spp.; and Siberian pea-tree, *Caragana arborescens*, used to a lesser extent. Intermediate trees, between the edge and the center of the shelterbelt, were green ash, *Fraxinus pennsylvanica lanceolata*; and American elm, *Ulmus americana*; in all the shelterbelts an occasional boxelder, *Acer negundo*; ponderosa pine, *Pinus ponderosa*; and red cedar, *Juniperus virginiana*.

In order to create a forest condition, the trees were not trimmed or thinned and were protected from livestock by fences whenever necessary, except in one case, on the Joos farm, a part of the shelterbelt was used as a pasture. There browsing and stock trampling were definitely retarding growth and even killing some of the trees. In areas where there was no damage by livestock, the branches arose from the trunk

close to the ground and spread to intermingle with those of the next tree to form an almost fencelike windbreak. This was especially true of rows of Russian-olive and Chinese elm. In the older shelterbelts much dead wood and many broken tree tops and torn branches were found. These broken branches and trees often served as favorable nesting sites for mourning doves.

The problem was primarily one of finding nests, recording breeding and juvenile populations and determining the number of young brought off during the season. The shelterbelts were searched daily for nests and birds by slowly traversing alternate rows of the shelterbelt and carefully examining all likely nesting sites. Doves were counted as they flushed, and since most of them flushed close it was easy to tell whether they were adults or juveniles. Since the shelterbelts were always traversed more than once a day, there was a tendency to recount the same birds. In order to overcome that difficulty the trip in which the greatest number of doves was seen was used as the count for the shelterbelt that day.

During the investigation an average of slightly less than 20 breeding pairs of doves was estimated by sight count. As the summer progressed the population counts of the shelterbelts containing the most nests showed an increase in the number of juveniles out of nests. In June the five shelterbelts contained only six young, in July 12, August 16 and September nine. The young doves produced in each shelterbelt probably did not remain near their nests during the remainder of the summer but migrated as has been noted by McClure (1943).

As the investigation was begun on June 6, some of the first nesting probably was missed. From June 6 to 20, 15 empty dove nests were found, of which nine indicated use. Relatively speaking, those nine used nests were of a more substantial construction than the remaining six and also contained droppings. Since there was no way to determine the success of the used nests, they were merely recorded as such and consideration of them in the production of the summer was based on data gathered on the active nests found. Two other used nests, which were found later, were definitely used during the nesting season.

June, the first month of the investigation, produced ten nests with eggs or young, only four of which were successful. The greatest number of nests was begun during the last week in July, when six clutches were initiated. Another peak was reached in the second week in August when five nests were started. This is about a month later than McClure (1943) noted in Iowa and over a month and one-half later than the nesting peak in Alabama according to Moore and Pearson (1941). Nesting was consistently higher in August than during any other month of the study. Twenty nests were initiated in August, while 10 were started in June, 11 in July and two in September. After the second week in August, clutch initiation gradually diminished until the first week in September when the last two nests were found.

After climbing steadily all summer a fairly stable period of nesting activity was reached in August. The peak was reached during the week of August 13–19 when a total of 21 nests was incu-

bated or brooded. The number of active nests dropped after the last week in August from 18 to 12, and then to five during the second week in September. Nesting activity did not cease completely until September 25 when the last two young produced were successfully brought off the nest.

During the study 40 nests with eggs and three with young were found. Twenty-five (58.13 percent) of the 43 nests brought off 54 young or 1.8 young per successful nest. If the 11 empty nests found brought off a similar number of young, an additional 19 doves were produced. This made a grand total of 64 young produced during the season in the five shelterbelts under observation.

Seventeen (39.53 percent) of all the observed active nests brought off the entire clutch, while one (2.32 percent) brought off two of a three-egg clutch. The remaining seven successful nests (15.28 percent) brought off one young each. Eighteen (41.87 percent) of the total nests found were unsuccessful.

Seventy-four eggs were found in the 40 nests containing eggs. Thirty-two of the nests contained the average clutch of two eggs, seven nests contained one egg each and one nest had three eggs. Forty-nine (66.2 percent) of the eggs hatched and 41 (55.4 percent) succeeded in leaving the nest. The three nests found with young already hatched were not included in these figures since the original clutch sizes of these nests were not known.

The mean average breeding stock for the months of the summer was estimated to be 19.7 pairs or 39 adult doves in the five shelterbelts. These adult doves were known to have produced 45 young capable of leaving the nest. This is an increase of 114 percent over the average breeding population of the areas under study. With the grand total of 64 doves estimated to have been produced during the entire breeding season, the increase was 162 percent.

The number of active nests found in each shelterbelt varied from one in the Joos shelterbelt to 17 in the Jamestown College shelterbelt. Three shelterbelts, the Jamestown College, County Farm shelterbelt II and the Frey shelterbelt, contained 40 of the active nests, while the County Farm shelterbelt and the Joos shelterbelt contained the remaining three nests.

Of the 12 species of trees and shrubs found in the areas studied, seven contained active dove nests. The birds showed a preference for three species of trees: the Chinese elm which contained 13 active nests, the American elm and Russian-olive which held 12 nests each. The red cedar and ponderosa pine held two nests each and the remaining two were found in a honeysuckle and a green ash. The Eastern cottonwood, one or two rows of which were found in every shelterbelt studied, was never used as a nesting tree. The green ash was also found in all shelterbelts but held only one nest. Both of these trees were rather open and the possible crotches and branches which were flat enough to be used as nesting sites were usually exposed to wind and rain.

The average height of nesting trees was 13.9 feet and the average height of the active nests was 5.0 feet. There was a great variation in both the height of the nesting trees and the height of the nests. There were nests in 20-foot Chinese elms and three-foot red cedars,

while nests were found as high as 12 feet and as low as 1.5 feet from the ground.

Only two attempts of reoccupation of previously used nests were noted. The first occurred in a small red cedar shrub in the County Farm shelterbelt II. The first clutch succeeded when two young were brought off on July 11. One month later a second clutch was found in this nest but was abandoned two weeks later. The eggs were infertile. The second reoccupation attempt was found in the Jamestown College shelterbelt. The nest was found empty on June 13, but from appearances had been used during the spring. On July 27 a dove was flushed from the nest and one egg was found. Ten days later the nest was abandoned with only the single egg having been laid.

The use of other bird's nests by mourning doves was noted three times during the summer. Two brown thrasher's (*Toxostoma rufum*), and one robin's (*Turdus migratorius*), nests were found filled with twigs and full clutches were found in each case.

Twenty-five nests were affected by decimating factors. Eighteen were lost altogether, while seven managed to bring off at least one of the clutch. A variety of influences were responsible for complete loss of the nest. Eleven nests were abandoned, two were destroyed by wind and heavy rains, one was lost by predation and two by unknown causes. The seven nests that succeeded in bringing off at least one egg of the clutch were affected in several ways. Three nests had one infertile egg each. One lost an egg of a three-egg clutch when it was pushed out by the two already hatched young. In one nest an almost fledged young was killed by a Cooper's hawk, *Accipiter cooperi*. In two nests one of the brood disappeared after hatching.

As part of the study, all the nesting doves over eight days of age were banded whenever possible. In all 68 nestlings were banded. Twenty-nine of them were banded in the cemetery and the remaining 39 in the shelterbelts.

SUMMARY

The production of the mourning dove was studied in five shelterbelts near Jamestown, North Dakota. An estimated mean breeding population of 39 doves remained in the shelterbelts during the summer producing an estimated 64 doves, which is an increase of 162 percent. The peak of nesting was reached during the week of August 13–19 when a total of 21 nests was incubated or brooded. Nesting was begun about May 15 and continued until September 25 when the last nest successfully brought off two young. The birds showed a preference for three nesting trees, the Chinese elm, American elm and Russian-olive. Twenty-five nests were affected by decimating factors. Eighteen were lost altogether while the remaining seven managed to bring off at least one of the brood. Banding was carried out in connection with the study.

Approximately four pairs of doves nested to a mile, or about a pair to three acres of shelterbelt. Approximately 15 doves were produced to a mile, or about one to an acre.

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SEX AND AGE DETERMINATION IN THE AMERICAN COOT

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The American coot (*Fulica americana*), because of its lack of dimorphic plumage characters, presents a problem to the worker trying to recognize sex and age classes. During thesis research at the Museum of Vertebrate Zoology, I had the opportunity to work with 130 living coots, some of which were held in captivity for extended periods of time. Repeated attempts to sex and age these birds disclosed several techniques that may be of general utility and which are here reported. Some other aspects of this study have been published previously (Gullion, 1950*b*, 1951*a*, 1951*b*).

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[2] Acknowledgments for assistance, suggestions and criticisms are due the following: Drs. A. S. Leopold, F. A. Pitelka and A. H. Miller of the Museum of Vertebrate Zoology; Dr. L. M. Taylor of the Division of Poultry Husbandry, School of Agriculture, University of California; Paul Covel of the Oakland City Park Department; A. W. Miller and J. A. Blaisdell of the California Division of Fish and Game; numerous colleagues in the Zoology Department at the University of California, and my wife, Ardelle.

AGING

The productiveness of the species can be determined only by knowing what proportion of the population consists of birds of the year. Similarly, the effect of hunting pressure and general population dynamics can best be determined by watching the changes in the relative numbers of young birds in the population.

Bursa of Fabricius.—The bursa of Fabricius is widely used in game management as a method of determining ages in the Anatidae and Galliformes; the deep bursae of the young in these groups atrophy with age (*cf.* Gower, 1939; Kortright, 1942:32; Buss, 1946: 60–64). Checking this structure in a number of American coots, little correlative atrophy could be detected. Out of 14 birds first probed in late December or early January, only four gave evidence of bursal decrease by late June and early July. The bursae in four decreased from depths of 30, 25, 20 and 28 mm. to depths of 16, 14, 10 and 15 mm. respectively. The other ten birds, whose bursae ranged from 15 to

30 mm., gave final depth readings either as long as or longer than the original ones.

Examination of preserved bursae from 57 birds, killed between November 16, 1949 and July 12, 1950, showed no size correlation with calendar dates. All birds killed in the spring and summer were found to have bursae as deep as those from the previous fall. The largest bursa seen, 40 mm. deep, was on a bird killed February 2, 1950. A random sample of this sort, as large as it was, should show a general decrease in depth with the advance of the season, if such occurs in this species.

A decrease in size may occur in the form of lateral shrinkage which cannot be detected by probing a living bird. A number of early season birds had bursae with an external diameter of from 4 to 7 mm. As the season progressed, more bursae fell into the 2 to 4 mm. class, and some were less than 2 mm. in diameter. This latter group became more frequent in the spring. Even though the bursae were much smaller in diameter, they still retained depths nearly as great as the flabby, fall season bursae.

However, several birds believed to be at least three years old had bursae completely closed over. As yet the season and age at which this occurs is not certain. One bird believed to be in at least its third winter when taken in January, 1950, had a bursa of 20 mm. By the last of June, 1950, this bursa had completely atrophied.

Unfortunately, no birds in juvenal plumage have been available for this work, so the final analysis is not yet possible, but the indirect evidence given above suggest that this method is of uncertain value in aging coots.

Leg color.—Although it needs more study, work to date indicates that the color of the tarsi of coots can be used to determine ages. This method has the advantage of allowing coots to be aged without being handled.

The characters as they appear to me in this stage of the work are: Blue- or gray-green tarsi on birds of the year; yellow-green tarsi on second year birds; and bright, clear yellow tarsi on birds in their third year. It was noted that there seems to be a progressive deposition of leg pigment so that as the bird grows older the leg color gradually tends towards a red-orange, which was the tarsus color of a banded, 11-year-old female picked up at Lake Merritt, Oakland, California, on March 20, 1950. This bird originally was banded at Lake Merritt on November 16, 1939.

My belief that leg color is suitable for aging coots is based partly upon observations on 14 birds held in captivity from October, 1949, and January, 1950, to July, 1950. Eleven of the 14 birds, when originally taken, had gray-green legs like 90-day-old immatures. Some of these green-legged birds began showing yellow in their tarsi as early as late February while others did not do so until early May. By mid-July all eleven had yellow-green legs. The appearance of the yellow-green was simultaneous with a molt of the leg scales.

The assertion that yellow legs are characteristic of adults is based on other evidence. It was noted that all birds defending territory through the winter possessed bright yellow legs. This was true not only among migrant birds on Lake Merritt but also among resident

birds on Lake Temescal, a small lake at the western base of the Berkeley Hills in Oakland. Furthermore, breeding birds trapped in 1949 at Jewel Lake, a small pond in the hills northeast of Berkeley, had bright yellow legs, and all birds breeding for at least their second year at both Lake Temescal and Jewel Lake had yellow legs.

The time of transition from yellow-green to yellow is not known. Two of the 14 captive birds had yellow-green legs when taken in January, 1950, and had shown no appreciable change by mid-August, 1950. This change may be simultaneous with the second annual fall molt of adult plumage, that is, when entering upon their third year of life.

Other evidence supporting the use of leg color for aging lies in the consistently lighter weight of green-legged birds (Fig. 1).

No attempt has been made to extract and analyze the pigment giving the tarsi their color, but from the general pattern of progressive deposition, leading to an orange color in old age, as well as the relative permanence of this color in the legs of birds after death, it is believed that the pigment must be a phaeomelanin. Perhaps even more indicative is the fact that coot legs can be kept in alcohol for more than six months without any loss of color.

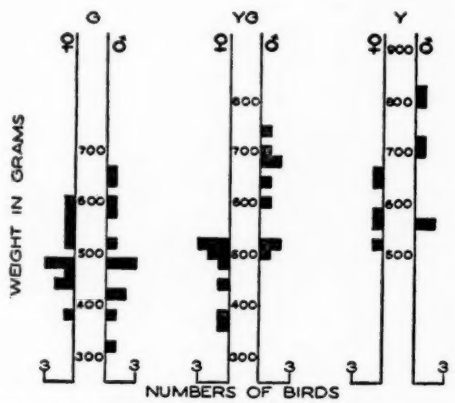

FIG. 1. Weights of 3 age classes of coots; G—first year, YG—yearling, Y—adult.

Other characteristics.—Various other characters were checked for their suitability in aging coots and all were found to be unsuitable. I believed at one time that the presence of white tips on underwing coverts might be diagnostic of young but found later that the 11-year-old female from Lake Merritt had this character. The same proved to be true regarding the presence of white tips on belly feathers.

SEXING

Voice dimorphism.—It was found that sex can be determined accurately in the field by voice characteristics. Since this is the subject of a paper already in print (Gullion, 1950*b*), it will not be discussed further. However, it might be pointed out that Grimeyer (1943) says that the only reliable way to sex the Old World's Black Coot (*Fulica atra*) in the field is on the basis of voice.

Displays.—Not only is it possible to sex adult coots by their calls but it is also possible to sex them in the field by their displays. In those displays involving erection of a neck ruff (Gullion, 1950*a*:13–31), it has been found that males are capable of forming a much larger ruff than their mates.

Culmen and shield length.—Other characters have been tested for use in the field, but none has proved entirely diagnostic. Partly satisfactory may be the measurement from the posterior edge of the frontal shield to the tip of

the bill. Of 47 immature and yearling birds (18♀♀, 29♂♂, aged by leg color as described above) checked for this character, overlap was found involving 10 birds (21 per cent). The females ranged between 36.7 and 44.6 mm., the males between 43.2 and 49.7 mm. (Fig. 2). The 11-year-old female, discussed above, had a 48.1 mm. bill-shield measurement, but no similar measurements are available for yellow-legged males.

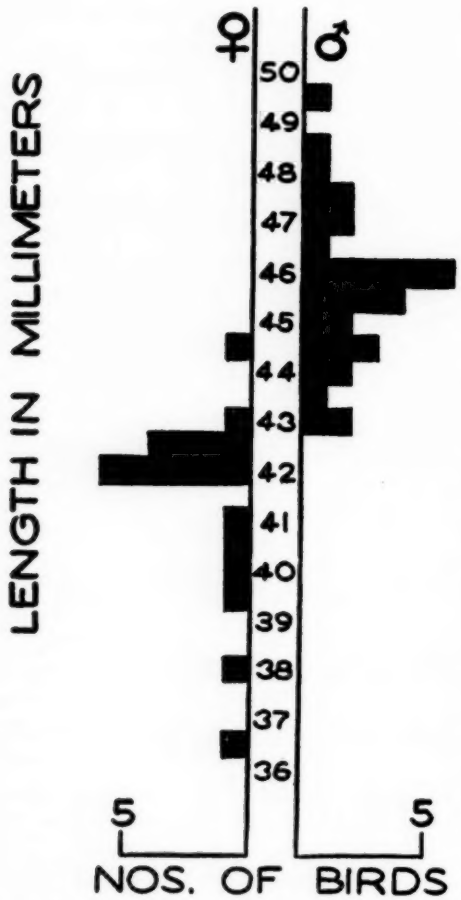

FIG. 2. The distribution of the culmen-frontal shield length by sexes.

Weights.—Weights have been checked, but a combination of overlap and impracticality for field use makes weighing of little use. Regarding weights, however, the average difference between green-legged males and females is very slight and the overlap quite complete, but among yellow-green legged individuals there is less overlap, with a difference of 154 grams between the average weights of nine males and nine females. The extremes for yellow-green legged females were 379 and 523 grams, for comparable males, 518 and 740 grams. The samples of yellow-legged birds were less adequate. Five females ranged from 533 to 666 grams, averaging 598 grams, while six yellow-legged males ranged from 567 to 829 grams, averaging 108 grams more than the females, or 706 grams (Fig. 1). Interesting in this regard is a statement by Walkinshaw (1940:164) concerning the Virginia Rail (*Rallus limicola*), Sora (*Porzana carolina*) and Yellow Crakes (*Coturnicops noveboracensis*) in which he says, "although there is some overlapping in the weights of the sexes, the males average considerably higher than the females."

Leg length.—Another criterion, suggested by A. W. Miller, was tarsal length. Although Engels (1938:606) showed that "males average about 7% larger (longer) than females in all parts of the skeleton" and that there is a six per cent difference between mean tarsal lengths of male and female coots, I found this method to be less than 60 per cent reliable for determining sex. This proving unsuccessful, the combined metatarsus—mid-toe length was checked and found to be somewhat more reliable, but still far short of 100 per cent (Fig. 3A,B).

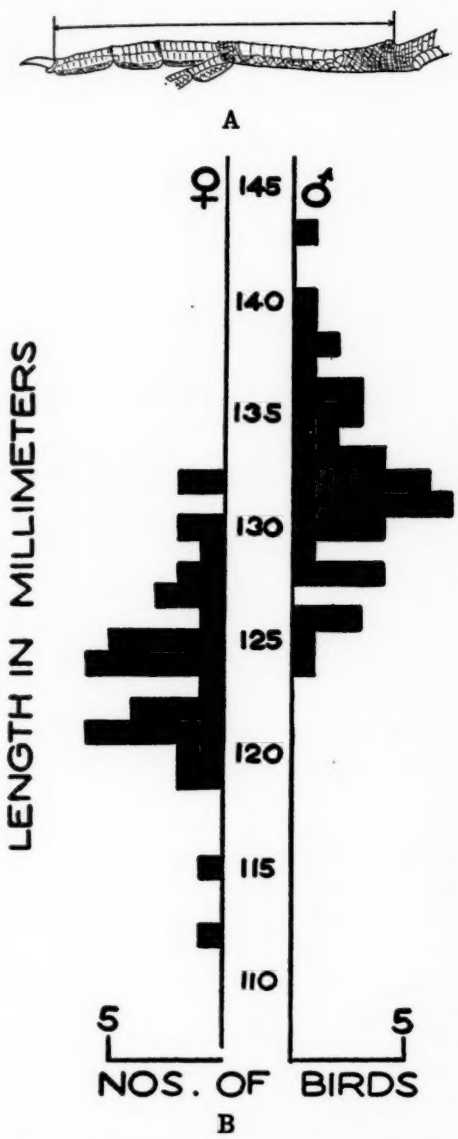

FIG. 3. Metatarsal—mid-toe measurements. A. The measurement, B. The distribution by sexes.

Working with 84 samples (39♀♀, 45♂♂, sexed internally), it was found that all metatarsus—mid-toe measurements above 132 mm. proved to be males and all below 124 mm. were females. Thus out of the 84 samples, 35 (42 per cent) could be sexed with certainty. Furthermore, 85 per cent of metatarsus—mid-toes 128 mm. or longer belonged to males while 87 per cent of those 127 mm. or less belonged to females. While these differences are not statistically significant, they are reasonably accurate and can be used on living, fighting coots. I have been able to sex 59 out of 67 birds for an 88 per cent accuracy by using this method. The errors, with three exceptions, were caused by small males.

For a time I believed that the metatarsus—mid-toe ratio was different between the males and females, at least it appeared to be so in the living bird. A check of a series of legs revealed remarkably similar ratios with no value whatsoever. Not even an age difference was discernible.

SEX AND AGE RATIOS

Basing sex and age ratios on leg color and leg length, some interesting sex and age ratios can be derived from 123 of the birds handled during the course of this study.

Sex ratio.—The overall sex ratio was 108♂♂:100♀♀ for all birds taken at Lake Merritt, Gray Lodge Refuge in Butte County, California and near Terminous, San Joaquin County, California.

Age ratio.—The ages of the birds procured from Gray Lodge, Lake Merritt and Terminous were as shown in Table 1.

The distorted age ratios at Terminous and Lake Merritt are not entirely understood. The refuge and artificial feeding at Lake Merritt may account

TABLE 1.—SEX AND AGE RATIOS

Locality	♂	♀	Adult (yellow legs)	Yearling (yellow-green legs)	Immature (green legs)
Gray Lodge.....	42	37	1	15	63
Lake Merritt.....	14	15	10	1	18
Terminous.....	8	7	..	10	5

in part for the preponderance of old adults there, but the reasons causing a shortage of yearling birds is not clear. It may be possible that the severe fowl cholera epidemic which swept this lake in the winter of 1948–49 caused excessive decimation among birds of the year, which would have been yearlings in 1949–50 when my work was done.

The age ratio of birds taken at Gray Lodge was 100 immatures : 24 yearlings : 1.6 adults. It is perhaps noteworthy that the first two figures correspond closely with similar ratios obtained by Buss (1946:103) on Wisconsin ring-necked pheasant (*Phasianus colchicus*) populations. His ratio for birds in their first, second and third-plus years was 100:26:13. The low number of adults in the Gray Lodge sample can be explained by the fact that during the trapping period a large number of coots were on territory, and could not be taken generally. These supposedly would all be adults. Hence, the only adults likely to be trapped would be the very few wandering unmated birds and any adults occupying territories in which traps were placed. The actual ratio would probably be 100:24:10 or 12.

DISCUSSION

The major problem that arises in the use of measurements for sexing is that of geographical variation. The winter population sampled in this study was probably heterogeneous in origin. The birds from Lake Merritt were all migrants, some of them breeding as far away as northern Canada. The birds from Gray Lodge are also of mixed origin, some being local stock and others from as far away as the Canadian prairie provinces. Perhaps with this in mind, the uniformity of the measurements is more surprising than the variation, since the birds of more northern origin would be expected to be larger than those of local origin.

The use of the swollen frontal shield as a basis for determining either the sex or age of a coot is of questionable value. Extensive experimentation with hormones and transplantations, plus a great deal of field observation, has shown that shield enlargement is completely dependent upon the state of territorial and breeding activity of the individual bird and has no relationship to sex or age. True, of a pair of coots in corresponding states of territorial or breeding activity, the female will have the smaller shield, but this shield may be much larger than the shield of an older male in non-territorial condition. A complete discussion of the subject appears elsewhere (Gullion, 1951*b*).

SUMMARY

Two methods were found to be useful for sexing coots; vocal differences being 100 per cent reliable and the metatarsus—mid-toe length being 86 per cent accurate if all birds having a length of

over 128 mm. are considered males and those under, females. Several other techniques were examined but proved inadequate.

Leg color is believed to be the most reliable means by which age classes can be separated. The three classes, *i.e.* green, yellow-green and yellow, can easily be distinguished in the field after a person has worked with a small representative sample in the hand. The bursal method of age determination does not seem to be reliable for aging coots, at least for separating first and second year birds.

The even sex ratio, *i.e.* 108♂♂: 100♀♀, is that expected of a monogamous species. The age ratio and rate of survival among coots at Gray Lodge Refuge, determined on the basis of the sex and age criteria discussed before, was believed to be 100:24:10 or 12 for first, second and third-plus year birds.

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FLUCTUATIONS IN GRAY FOX POPULATION IN PENNSYLVANIA AND THEIR RELATIONSHIP TO PRECIPITATION [1]

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An examination of the Pennsylvania Game Commission bounty records for the last thirty-five years discloses a remarkable change in the relative number of weasels and foxes offered for bounty during the period 1936–1946. The number of weasels offered for bounty declined from approximately 80,000 in 1936 to 6,000 in 1944, and the number of gray foxes increased from their previous high of 11,000 in 1939 to 21,000 in 1946.

It is believed that the extreme changes in the bounty figures since 1935 reflect actual population trends. With this evidence of bounty data as a population index, a study was made of the fluctuations in the number of gray fox in Pennsylvania.

Since 1944, the number of foxes of both species has been at an all-time high in Pennsylvania, as well as throughout most of the northeastern states. It is generally thought that this marked increase in numbers is the result of reduced trapping pressure during the war years caused by the drop in price of fox fur, and by the number of trappers who were in the armed services or employed in war industries.

As an indication of the amount of trapping pressure on foxes during the war years, we have the bounty records for those years showing the number of gray foxes on which bounties were paid. (The figures used are totals for the entire state.) The number of gray foxes bountied has increased steadily since 1941, and during the four years, June 1942 to May 1946, bounty was paid on 47,760 gray foxes. During the highest previous four-year period, June 1936 to May 1940, there were 38,660 gray foxes presented for bounty.

The number of people employed in war industries and in the armed services reached a maximum in 1944, and continued with little change until late 1945 or early 1946. Yet during the war years more gray foxes were offered for bounty than in any previous four-year period in the history of the bounty system in Pennsylvania!

When the population of foxes increases to the extent that it has since 1940, it poses serious problems not only to the game manager, but to agriculture and to public health as well. At the same time, any such extreme deviation from previous population levels offers a rare opportunity to examine all of the factors, economic and environ-

[1] Study made in connection with Survey of Pennsylvania Mammals, 1946–1951, Pittman-Robertson Projects, Federal Aid in Wildlife Restoration Program.

The author wishes to express his appreciation to Robert D. McDowell, Chief Wildlife Research Division, Pennsylvania Game Commission, for his encouragement and cooperation throughout the course of this study; and to Miss Lillian Heeren for her preparation of the graphs.

mental, that might affect foxes, and to discover what factor, or combination of factors changed to the same degree.

Most of the fox studies reported in the literature deal with the evaluation of the destructiveness of foxes, their food habits, or control methods. Only a few have dealt with life history, and none has dealt with the problem of what the natural limiting factors are that act to control the density and distribution of fox populations although as early as 1931 Leopold reported evidences of natural control in fox populations in the mid-west. (Leopold, Aldo. Game Survey of the North Central States, Madison, Wisconsin, 1931, p. 224).

At present there is nothing in our knowledge of the life history and habits of either of the foxes that will satisfactorily explain their increase since 1940. In Pennsylvania, the increase of gray foxes has been, in a large measure, an expansion of their optimum range, as well as an increase in numbers in the counties where they have always been common. (Figure 3.)

Although the gray fox had been taken in every county in the state, it was so scarce as to be a novelty in the extreme northwestern counties in 1937. In that year, five central counties produced 27% of the gray foxes offered for bounty. By 1946, gray foxes were common over the entire state, and the same five-county area made up only 11% of the total offering. The difference was accounted for largely by the increased number of foxes from all other counties. The greatest increase occurred in those counties in which the gray fox had formerly been considered scarce. In some areas it is reported that the gray fox, once rare, is now replacing the red fox.

The bounty data used in this study

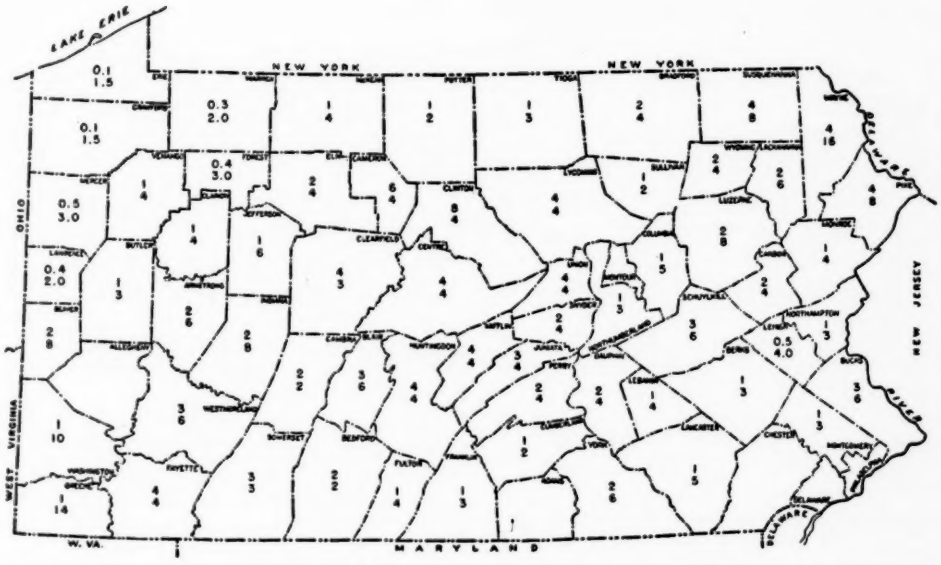

FIG. 3. Number of gray foxes offered for bounty per 10 square miles. The upper figure in each county is for the fiscal year 1937–38. The lower figure in each county is for the fiscal year 1946–47.

are taken from the Pennsylvania Game Commission bounty records compiled monthly and summarized annually. The yearly summaries are for the fiscal year, June 1 to May 31. On the graphs, the figures for one fiscal year are plotted in the first year. For example, the data for the fiscal year 1945–46 are plotted in the year 1945 and are compared with the weather of the calendar year 1945. The weather data are from Climatological Data Pennsylvania, U. S. Dept. of Commerce, Monthly and Annual Summaries. Where smoothed averages are used, the data were smoothed by a weighted three-year moving average using the formula $\frac{a + 2b + c}{4} = b'$.

Since the usefulness of bounty data is dependent upon the manner in which they are obtained, it is noteworthy that the bounty system in Pennsylvania has operated continuously in its present form since 1915. (Gerstell, Richard. 1937, The Pennsylvania Bounty System, Research Bulletin No. 1, Pennsylvania Game Commission, Harrisburg, Pennsylvania).

The number of gray foxes offered for bounty each year since 1915 is shown in Table 1 and in Figure 1A. It is apparent in this curve that although the number of foxes killed fluctuates from year to year, there has been a gradual tendency toward the increase culminating in the abrupt increase between 1941 and 1946. This is especially evident if we compare the annual average take for each of the last three decades (to the nearest thousand): 1920–29, *7,000*; 1930–39, *9,000*; 1940–49, *14,000*. The annual average for the entire thirty-five year period since 1915 is *9,000*. In the last six years, 1945 through 1950, the number of gray foxes presented for bounty has ranged from *15,856* to *20,985*, or an annual average of *18,000*.

It can be assumed that the great increase in foxes offered for bounty in this period reflects an actual population change rather than changes that might influence the percentage of foxes that are killed or offered for bounty since there has been, in the last ten years, a widely recognized general increase in fox populations throughout the North East. Another evidence that the fox bounty curve reflects actual population trends is the increase of gray foxes taken in counties where they were rare prior to 1940. In some of these counties the increase in numbers of gray foxes was so rapid that many hunters and trappers think of it as an actual migration into these areas. (Figure 3).

Since it is possible to identify a portion of the fox bounty figures with changes in fox population, then it be-

TABLE 1.—ANNUAL NUMBER OF GRAY FOXES PRESENTED FOR BOUNTY SINCE 1915 *

	0	1	2	3	4	5	6	7	8	9
1910.....	....	....	....	.....	.....	4748	3758	3287	4446	4718
1920.....	3068	5393	4530	7730	7177	8339	6648	9980	6955	7917
1930.....	6458	6567	9392	9337	9487	8408	9790	8919	9432	10519
1940.....	9503	6646	8032	10354	10230	19144	20985	16951	17770	15856

* The data for each fiscal year, June 1 to May 31, are given above in the first year. For example: the number of foxes shown in 1915 is for the fiscal year 1915–16.
Rate of payment: $2.00 1915–1922; $4.00 1923-to date.

comes possible to use this period in an effort to locate factors that could produce such a change. A search was undertaken to find a factor, or combination of factors, that would show a degree of change between 1940–1946 not duplicated since 1915, with similar, although lesser, changes in previous years that might be correlated with the relatively minor changes in the number of foxes during that time.

Rate of land abandonment, changes in agricultural or forest practices, and stage of plant succession on abandoned lands were examined as possibilities, but they did not comply with either of these qualifications although these factors probably contributed to the general upward trend in the fox population since 1915.

Since the years in each decade that had the highest number of foxes killed were relatively wet years, it appeared that there might be some correlation between years of high precipitation and high fox populations, but a detailed comparison of the precipitation records for the state and the bounty records did not support this. Because the figures for the annual amount of precipitation are subject to considerable distortion by brief periods of excessive rainfall, the frequency of precipitation was selected as being more nearly indicative of the wetness of a particular year. When the figures for the annual number of days

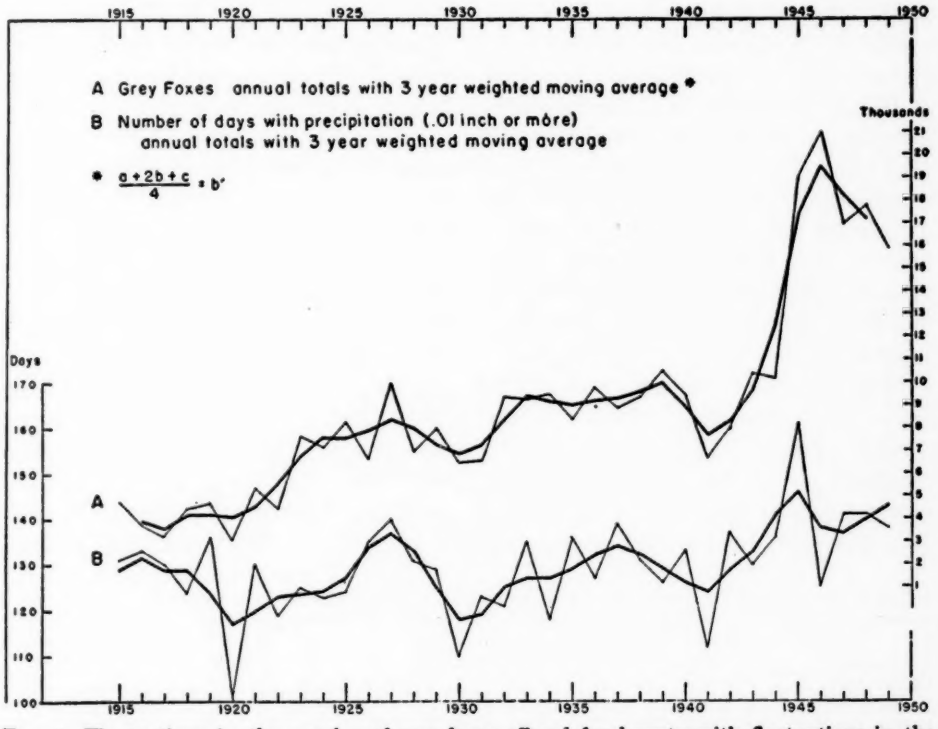

FIG. 1. Fluctuations in the number of gray foxes offered for bounty with fluctuations in the frequency of precipitation in Pennsylvania.

with measurable precipitation (.01 inches or more) were plotted (Figure 1B), it was immediately apparent that the period 1942–1950 was unusual in the large number of days with precipitation. Similar to the fox data, the curve shows a generally upward trend since 1915, with a sudden marked increase to a record high in 1945.

Comparing the two sets of data, it can be seen (Figure 1) that the years in each decade that had the highest number of foxes offered for bounty were also the years with the greatest frequency of precipitation. The lowest number of foxes killed in each decade occurred in those years with the lowest frequency of precipitation. If we compare the last twenty-nine years (1920–1948), the smoothed curves for this period are remarkably similar and have a coefficient of correlation of $+.80 \pm .05$. Outstanding is the remarkable increase shown in both curves between 1941 and 1945. It is apparent that whatever the limiting factors of a fox population are, they vary with measurable changes in the weather, and as the annual number of days of precipitation has increased, the number of gray foxes has increased.

However, the frequency of precipitation cannot directly and alone limit the number of foxes. The most logical interpretation of this paradox is that changes in the frequency of precipitation represent a summation of changes in the total weather. Like most of northeastern United States, the normal weather of Pennsylvania is characterized by frequent precipitation of relatively small amounts evenly distributed throughout the year. In this state, each month has approximately three and one-half inches of precipitation distributed over eleven days (See Table 2). With the exception of local convective storms during the summer, most of the precipitation in Pennsylvania is the result of frontal interactions that take place along cold fronts as they move east and north across the state. Although the intensity of the storm may vary greatly from one locality to another, resulting in large local variations in the amount of rain or snow, this extreme local variation is not seen in the figures for the frequency of precipitation. Such variation as occurs, tends to be regional and more or less constant.

When rain is produced along a storm front, it represents the culmination of a series of events that had their origins in the tropics and in the arctic, and in the relative intensity and distribution of the principal areas of high and low air pressure throughout the world. With the passing of each storm front, there are associated local changes in direction and velocity of wind, temperature, barometric pressure, humidity, evaporation rates, cloudiness and amount of sunshine. Since precipitation is the end result of the interaction of many factors,

TABLE 2.—MONTHLY AVERAGES OF TEMPERATURE AND PRECIPITATION FOR PENNSYLVANIA

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Aver. temp.....	28.5	28.4	37.7	48.6	59.6	68.1	72.1	70.3	64.0	52.7	41.4	31.2	50.2
Days precip.*.....	11	10	12	11	12	11	11	10	9	9	10	11	127
Inches precip.....	3.17	2.78	3.50	3.44	4.03	4.13	4.33	4.13	3.40	3.21	2.96	3.07	42.08
Inches snow.....	10.4	10.6	7.8	2.0	T	T	T	T	T	0.2	2.8	8.0	42.0

* Number of days with .01 or more inches of precipitation.

then a record of the frequency of precipitation should serve as an index to the frequency, but not the extent of, associated changes. In other words, the number of days of precipitation is an approximate numerical expression for many of the physical changes that living things experience as "weather." Certainly the number of days with precipitation is a better measure of a "wet season" than are inches of rainfall. An examination of Figure 4 shows that since 1900 the weather, as indicated by the frequency of precipitation, has varied in periods of approximately ten years, with the latter half of each decade wetter than the first half.

To determine whether or not there was any month or season during the year that was more important in affecting the number of foxes, the month of least variation was determined using the method described by V. E. Shelford, (1951, "Fluctuation of Non-forest Animal Populations in the Upper Mississippi Basin", Ecol. Monogr. **21**: 149–181, p. 153). The three years of the greatest increase, 1927, 1939 and 1945, were compared month by month to show the relation of the two factors, monthly mean temperature and frequency of precipitation. The first six months are shown in Figure 5. In the three years of the maximum increase in the gray fox population the month of February shows the least variation and ranged from two to three days more precipitation and the monthly mean temperature was 1–7° F. warmer than average. As an additional check on this method a similar comparison was made of the three years when gray foxes were at their lowest level, 1920, 1930 and 1941, (Figure 5). In this series March shows less variation than February, but especially noteworthy is the general shift in the first three months of the years towards warmer and wetter weather

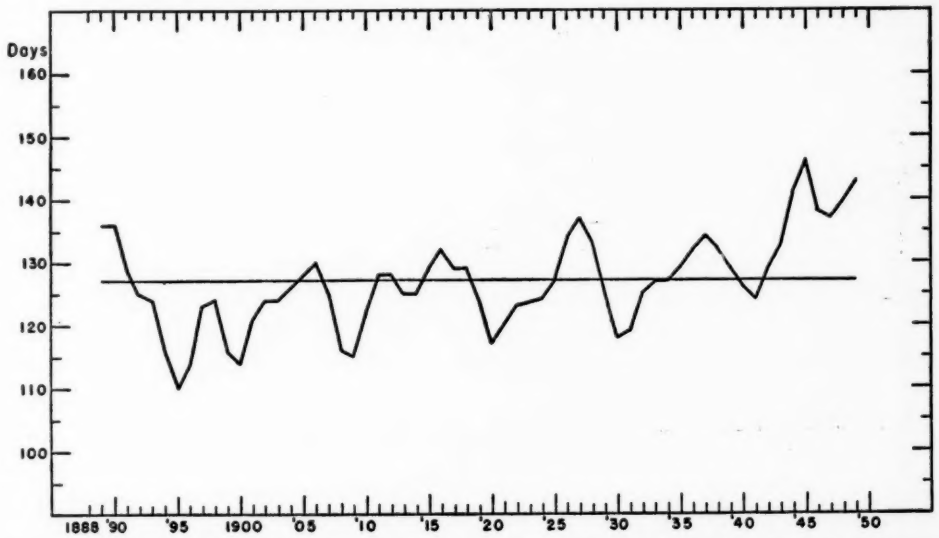

FIG. 4. Weighted 3 year moving average of the annual number of days with .01 inches or more of precipitation. The straight line represents the average for the period, 127 days.

in the years of high fox population and towards colder and drier months in the years of low fox population. And of particular interest is that the year with the greatest increase in foxes, 1945, every month except August had 2 to 6 more days of precipitation than average (Figure 2).

Shelford found that the most critical period in the life cycle of many of the populations he studied was the period of or just prior to reproduction. The same appears to be true of the gray fox as in Pennsylvania the mating season of the gray fox starts in January and extends into March, with the peak of the mating activity occurring in February.

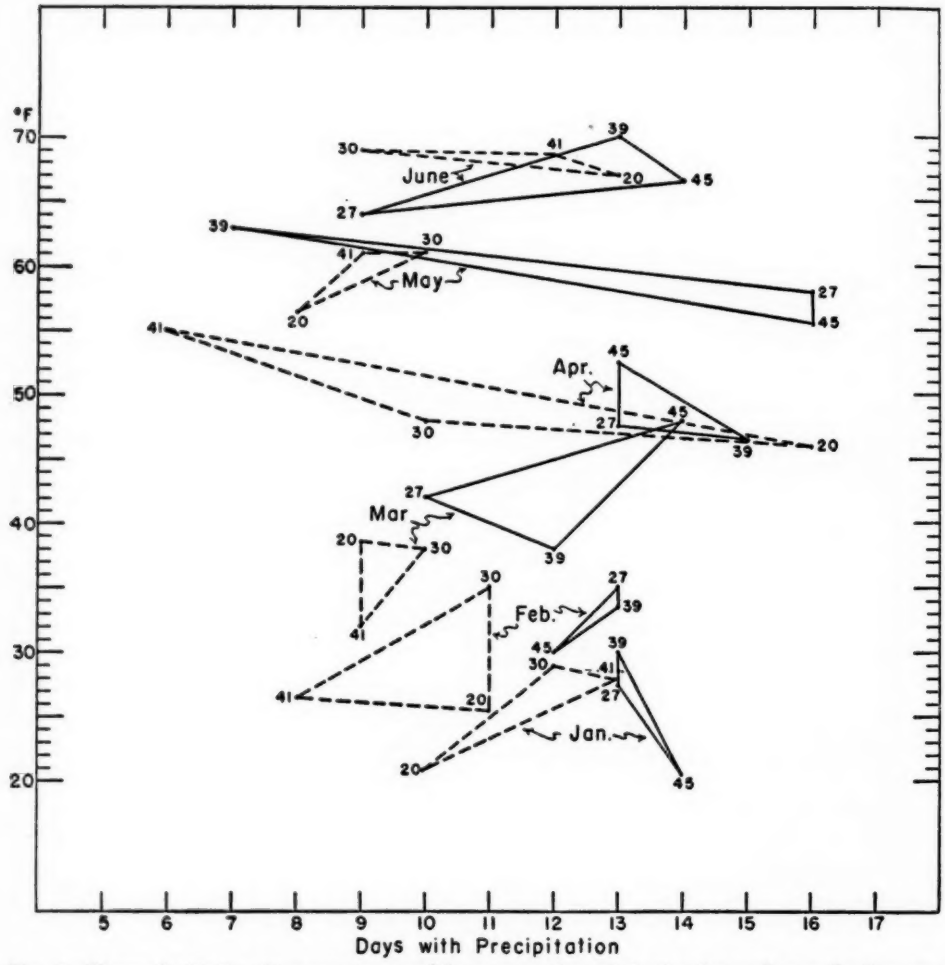

FIG. 5. Shows the limits of temperature and frequency of precipitation for each month, January to June, in 3 years when foxes increased the most, solid line, and in 3 years when foxes were at their lowest levels, broken line. January, February and March are considered to be the most important months. Temperature used is the monthly mean and precipitation is the average number of days with .01 or more precipitation.

The mechanism by which changes in the physical environment influence the population level of foxes remains a mystery. But we are closer to a solution of this problem when we find measurable environmental factors that have changed at the same time and in a similar degree to the changes observed in the fox population.

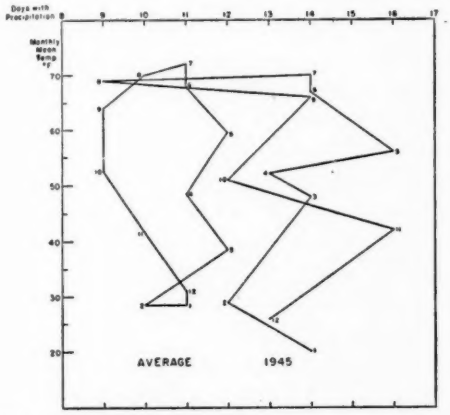

FIG. 2. Temperature—precipitation graph for Pennsylvania. Monthly mean temperatures and monthly number of days with precipitation (0.01 inches or more) is shown for 1945 and the average for period of record.

Although man appears as the greatest single enemy of foxes, there is no evidence that the efforts of man have been able to control the number of foxes in Pennsylvania. To look at the problem another way: why should the gray fox population in Pennsylvania yield approximately 8000 pelts annually for twenty-five years, then in three years increase to an annual yield of 18,000? Obviously, some control other than man has been operating because we now see that the population of foxes was potentially able to increase to its present levels, but for twenty-five years it remained more or less stable.

The concept that each species has a "normal" density about which it fluctuates seems to have no basis in nature other than as it appears for the relatively short periods of time covered by observation. Actually a species tends to fluctuate between complete extinction and an indefinite increase. Environments have finite limits of capacity in terms of available food and space, and less finite limits in terms of factors peculiar to each species such as tolerance of crowding, limited nesting or overwintering sites, number of suitable habitat niches, and other limitations of the total environment that may operate to restrict population density to levels lower than the available space or food would determine.

Populations of animals in nature can increase in two ways: by an actual increase in density in habitats already occupied by the species, or by expansion into habitats previously unoccupied or unsuitable. Where the second method of increase occurs on the periphery of a species' range, it may amount to an extension of the species' geographic range. As long as increase in numbers takes place by the second means, the so-called density effects are not likely to occur, but when the numbers of a species increase in habitats already occupied, then the very density of the population may act to limit its increase. This may act through a decreased amount of food, an increase in fighting, or other mutual interference, or in a marked increase in disease and parasites. In gray foxes, the increase appears to have been in habitats previously unsuited as emphasized by their increase in areas where they once were scarce, (Figure 3), and the increased suitability

of these areas is apparently related to climatic changes.

Since all of Pennsylvania is within the geographic range of the gray fox, then the differences, for example, between Erie County and Clinton County gray fox populations in 1937 would seem to be the difference in the carrying capacity of the two areas, and the fact that the carrying capacity of these areas has changed in direct relationship to a climatic factor seems to indicate that not only can climate control the geographic distribution of a species, but it can also control their numbers, especially at the periphery of their range.

CONCLUSIONS

1. Bounty data, when obtained as in Pennsylvania, form a useful indicator of population trends. Although the ratio of animals killed to the total population may vary to an unknown degree, apparently population size has a greater effect on the total killed than do other factors.
2. The first three months of the year are the critical months in determining the size of the gray fox population. In the thirty-five year period studied, marked increases in the number of gray foxes were in years with January, February and March wetter and warmer than average. And the lowest fox populations were in years when the same months were colder and drier than normal.
3. Gray foxes in Pennsylvania are subject to a natural control that is correlated with the frequency of precipitation. Since frequency of precipitation represents an integration of several meteorological changes, it remains to be determined what factor in the integration is critical, how it operates to control population levels, and whether or not it affects the foxes directly or in some manner changes the effectiveness of other controlling factors.
4. The Pennsylvania weather data that have been examined show sequences of deviations above and below the average, and for frequency of precipitation, these have occurred at ten year intervals since 1900 (Figure 4). However, there have been too few of these departures to determine whether or not they are true periodic occurrences. For most wildlife studies the question of periodicity is of little importance although it is of great importance to recognize that meteorological phenomena may vary in sequences of eight to twelve years, and often with long term trends of thirty or more years of increasingly colder, warmer, wetter or drier years. This feature of the weather becomes especially significant when it is realized that most studies of wildlife problems, or of population behavior, last for only two to five years, during which time the weather may be becoming more or less favorable for the species under study.
5. It is hoped that one of the results of this paper will be to call attention to the remarkable changes in the weather that took place between 1935 and 1950, and to focus attention upon the possibility of this period as one that will aid in interpreting some of the data now available on population trends.

PRELIMINARY LIVE-TRAPPING STUDIES OF MARTEN

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and

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and
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Very little is known about the movements of the pine marten (*Martes americana americana* (*Turton*)). However, for improved management there is need for more information on its home and seasonal range, and movements in relation to cover. It was with this idea in mind that the authors started their movement studies.

The following information on marten movements could be obtained from the literature. Marshall (1942) followed the tracks of individual pine martens in two different study areas in Idaho during January and February. He studied the movements of one animal over a five-week period, and those of another one during a few days. The areas covered by these martens during the two instances cited were approximately fifteen and twelve square miles respectively. He states: "The pattern of movements is an adjacent or overlapping series of small areas that change more or less each day. In a complete cycle the animal tends to return to identical favorable hunting spots but the tracks by no means always follow those of the previous trip." Davis (1939) estimates that the foraging circuit varies from 10 to 25 miles in diameter, and Grinnell, *et al.* (1937) report similar travels on the basis of trappers' statements.

Several workers describe the movements of the European spruce marten (*Martes martes martes* L.). Schmidt (1943) asserts that although the animal moves long distances it tends to remain within a well-defined area. Dulkeit (1929), a Russian worker, describes a "hunting plot", averaging two to nine square miles, which is divided into "hunting sections", averaging six-tenths of a square mile. Another Russian worker, Kozhantschikov (1930), states that the size of the individual range differs with timber types and varies from about three-quarters of a square mile to over four square miles. Malaise (1929) estimates the home range to be nine to eleven square miles.

Tracking studies provide useful information regarding daily movements and, in exceptional cases, those over a period of a few weeks, but they cannot be used for longer periods. An attempt was, therefore, made to initiate a live-trapping and tagging program. Although results are not conclusive as yet, it was decided to compile the information obtained so far, in order to encourage similar studies. This paper discusses the findings of live-trapping studies in restricted areas in Washington and Ontario.

Contrary to what is ordinarily stated, martens do not appear to be very

arboreal in habits in either study area. They traveled on the ground practically all the time, as noted also by Marshall (1942). In Ontario evidence was found only twice of a marten climbing a tree (de Vos, 1951). In Washington one marten was discovered in a tree apparently after having taken the bait from a steel trap. This animal crossed through three large trees before being lost from sight. While in Ontario none of the trapped martens climbed a tree upon release, in Washington one did and stayed there. Because of these ground dwelling habits, martens can be most readily trapped in live traps situated there.

TRAPPING TECHNIQUES

Martens can be trapped alive in box traps and in steel traps with padded jaws. The use of the latter trapping method is not recommended, as the captured martens will struggle violently, and often may not survive after release. It was found in Washington that leg bones are often broken in steel traps and that sometimes a foot is lost. Collapsible and non-collapsible live-traps were used. The "Havahart" type trap, produced by the Allcock Manufacturing Company, Ossining, New York, was tried out in Ontario, and although martens were captured in it, the animals often managed to escape. Moreover, this trap is too bulky to be carried over long distances. It was found that the collapsible live-trap produced by the National Live Trap Company, Tomahawk, Wisconsin, is the most useful model. Both the 6″ x 6″ x 19″ and the 9″ x 9″ x 27″ models have been used with about equal success. The larger model has the disadvantage of also catching foxes and skunks.

Live-trapping of martens requires knowledge of their movements, which may be obtained by winter tracking studies, as well as trapping skill, as indicated by Swanson (1949). The technique used in Ontario is still developing and it can be expected that by the selection of the most suitable baits, scents and trapping periods, the catch can be improved. The use of live bait instead of dead animals may increase the trapping success. Although a few martens injured their claws and broke their teeth while trying to escape, very few died in the collapsible cages if they were checked daily.

TRAPPING RESULTS

In Washington the study was started in 1948. Trapping was undertaken during the late winters of 1948, 1949 and 1950 in an area closed to trapping for fur, situated around Twin Lakes in Chelan County. This area, enclosing one watershed, is long and narrow, averaging about five miles in width. Traps were set along a trap-line fifty to five-hundred yards from the lake shores. All the martens which were released were liberated at the place where they were caught (Fig. 1). Marten movements are shown on Fig. 1, which is a map of the study area. It indicates the locations of trapping and tracks observed of martens that may not have been trapped.

In 1948 nine martens were trapped during the period March 5th-19th (Fig. 1, animals #1–9). Six of these were released. Two of these animals were recaptured once again, while two others

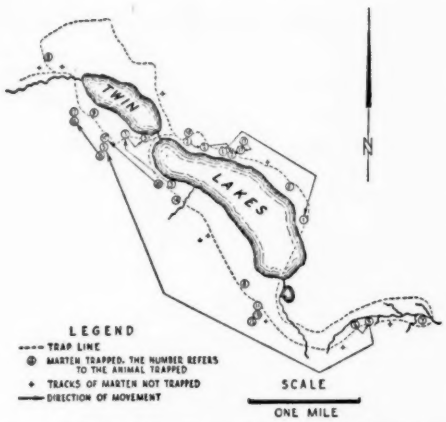

FIG. 1. Map of the Twin Lakes area, Washington, showing trapping locations and marten movements.

were recaptured twice. In 1949 seven martens were trapped (Fig. 1, animals #10–15) during the trapping period April 7th-15th. All were released again. Three of these were retrapped in the vicinity of the site of capture and again released. One adult female (Fig. 1, animal #5), which was released in 1948, was retrapped approximately three miles from where she had been tagged a year previous. In 1950 only two martens were trapped and released again (Fig. 1, animals #16 and #17) during the period March 21st-31st. Continuous snowfall seemed to limit the travelling of the animals. One, an immature female, was retrapped. Upon release she ran several hundred yards on top of the snow. While doing so, she passed close to several large coniferous trees, but would not climb them, though she was closely followed.

In Ontario live-trapping was started in 1948 in and around Chapleau Game Preserve, which is situated roughly two hundred and fifty miles north-east of Sault Ste. Marie to the east of Lake Superior. The study was terminated in March 1951. Figure 2 shows the locations where martens were trapped, released, retrapped, and the movements of tagged individuals. Also are shown the spots where the local trapper caught martens in steel traps during the last thirteen years.

In 1948 during a period from September 14th to 27th six "Havahart" live-traps were tried. Only one marten was caught. It was moved to a point about twelve miles away, and released on the west shore of the Chapleau River on September 25th (Fig. 2, animal #1). In 1949 these traps were again tried during the period March 11th to 20th. One marten was trapped and released at the trapsite (Fig. 2, animal #2). Since several managed to escape either as a result of malfunctioning of the traps or by lifting the trap doors, it was decided to abandon the "Havahart" traps and to try the collapsible ones instead. During the period September 6th to 13th, three martens were caught and released near the trapsite (Fig. 2, animals #3, 4 and 5). During the period October 5th to 23rd four animals were trapped (Fig. 2, animals #6, 7, 8 and 9) and moved over different distances. Of these two females were caught in steel traps respectively on December 29th, 1949, and January 29th, 1950. The male marten which was released on September 25th, 1948, was caught in a steel trap on December 1st, 1949, at least twelve miles from the point of release (Fig. 2, animal #1). In 1950 live-trapping was started during the period August 16th to 28th. Two martens were trapped and released on the spot (Fig.

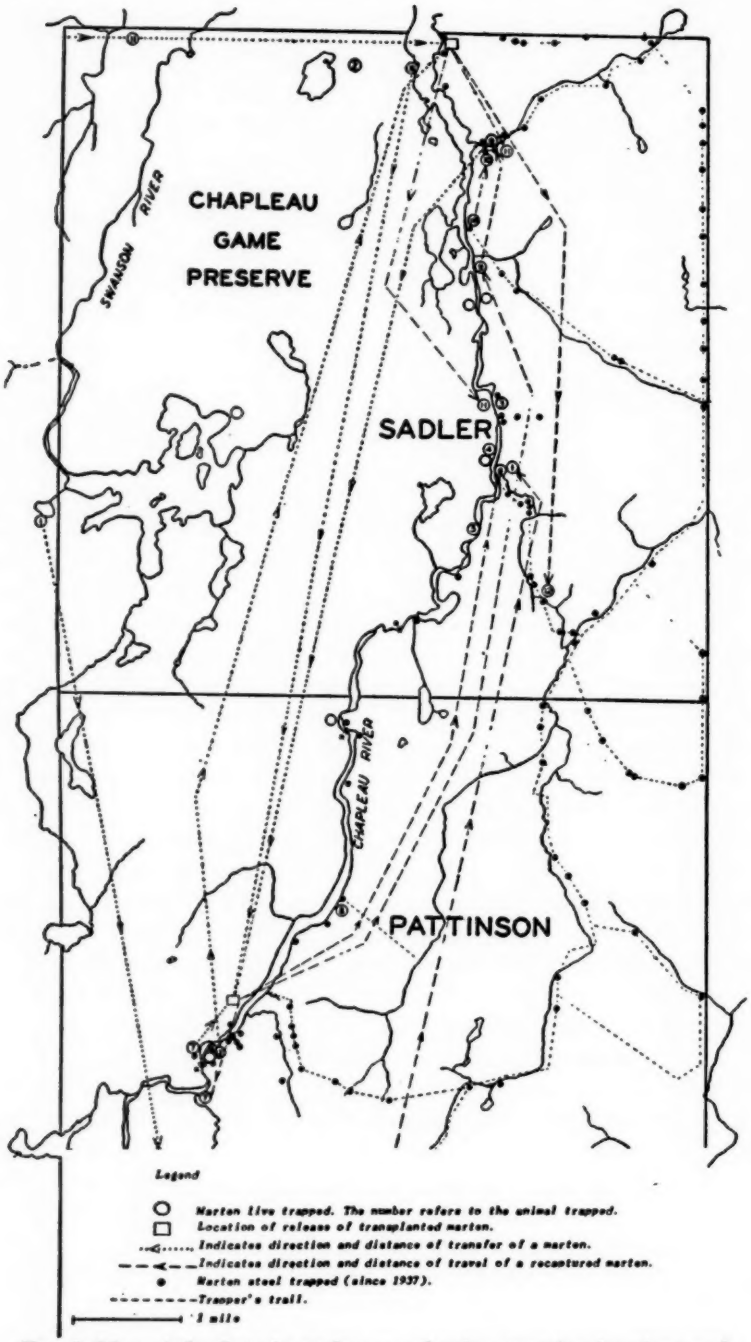

FIG. 2. Map of the Ontario study area, showing trapping locations and marten movements.

2, animals #6 and 10). One of these (#6) was recaptured on December 9th, 1949. During the period September 15th to October 14th, 1950, eight martens were live-trapped. Of these five were released in the area. One of these, a male, (Fig. 2, animal #11) was recaptured and returned to the place where it was released first. It was caught again in a steel trap on November 7th. Both times this animal, which was originally trapped in the Game Preserve (the location of trapping is situated outside the area shown in Fig. 2) travelled in a southerly direction. A female (Fig. 2, animal #12) was killed in a steel trap on November 13th. Finally, two males (#9 and 10) were retrapped respectively on November 7th and 20th.

Table 1 shows a tabulation of the trapping results obtained in both areas. A "trapping day unit" is a period of twenty-four hours per set trap.

DISCUSSION

Table 1 indicates that martens can be successfully trapped between early March and late October. During the coldest winter months live-trapping is not advisable, because the animals will die from exposure too easily. The lowest number of trapping day units required to trap one marten was fourteen, the highest ninety-six. The sex ratio obtained in the Washington study is one to one. The ratio in the Ontario study is thirteen males to five females, which appears unbalanced. The percentage of animals recaptured once during the three-years' period in Washington is 53%, that in Ontario is 56%. In both areas two animals were recaptured twice. This indicates a surprisingly high return of tagged martens. Possible explanations of these high returns are: (1) Apparently a considerable percentage of the resident population was trapped. (2) A large percentage of the population remained for a considerable length of time in the areas under study, which suggests the existence of a definite home range. In Washington several martens were retrapped a few days after release in the same set or within a short distance of it. Only one animal was caught bearing a tag of a previous year.

During the Ontario study no martens were recaptured within a few days of release in the same set, probably because most traps were moved after a

TABLE 1.—TRAPPING SUCCESS AND SEX RATIOS OF MARTEN TRAPPED

Trapping Period:	No. of trapping day units required to trap one marten in a live-trap:	Havahart Traps:	Collapsible Traps:	Steel Traps:	Adult Male:	Adult Female:	Juv. Male:	Juv. Female:	Percent Recaptured:
Washington:									
March 5–19, 1948....	19		12	12	1	3	3	2	66
April 7–15, 1949....	16		20		3	1	2	1	43
March 21–31, 1950....	74		22		0	1	0	1	50
					4	5	5	4	
Ontario:									
Sept. 14–27, 1948....	60	6			1	0	0	0	100
March 11–20, 1949....	74	6			1	0	0	0	0
Sept. 6–13, 1949....	14		6		1	1	1	0	0
Oct. 5–23, 1949....	45		6		2	1	1	0	75
Aug. 16–28, 1950....	96		13		1	0	1	0	100
Sept. –12, 1950....	38		18		5	2	0	1	60
					11	4	3	1	

marten was caught. Two martens were caught bearing tags of a previous year. That individuals may remain in a restricted range for some period, is indicated by the results of some live-trapping done by R. Y. Edwards in Algonquin Park, Ontario. During a period from August 12th to September 6th, 1950, he captured the same marten six times in three different traps situated on a portage of about ten chains long. Trapping dates were August 22nd, 24th, 27th, 29th and September 4th.

Table 2 shows the movements of martens in both study areas, and the number of days between the dates of release and recapture (compare these data with Figs. 1 and 2).

As martens do not move in a straight line, but wander around to a considerable extent, it does not seem to be of any value to compare the number of days travelled with the distances covered, in order to get a picture of the distance travelled per day. However, the recaptures of transplanted martens in Ontario indicate that considerable movements are possible.

The effect of transplanting on movements can only be guessed at this stage. It appears that at least some of the martens returned to what might be called their "home range." At any rate marten #9 was caught practically at the site where it was released a year previously. Animal #7 was captured one-third of a mile from the original trapsite, while martens #6 and #12 were more than half-way "home." Animal #1, which was transferred over a distance of twelve miles, was caught only four miles from where it was originally captured. Data are too limited to eliminate the possibility of chance.

Table 3 shows the major timber types tabulated, the number of trapsites where martens were caught, and the number of trapsites where none was trapped. The data appear too restricted to show conclusively which timber types are preferred by martens.

It appears from the Washington data

TABLE 2.—MOVEMENTS OF RETRAPPED MARTENS

Sex	Number: (on Maps)	No. days between date of release and recapture:	No. of miles travelled (Computed in a straight line):
Washington:			
MALE.....	3	3	3/4
"	3	5	1/4
"	10	7	3/4
"	15	3	1/2
FEMALE.....	1	4	1
"	2	2	1/3
"	2	2	1/10
"	5	1	1/10
"	5	334	3
"	17	2	0
Ontario:			
MALE.....	1	432	12
"	9	256	7
"	9	0	1¼
"	10	0	¼
"	11	24	3¼
"	11	0	1
FEMALE.....	6	51	5¼
"	7	20	1
"	12	34	5

that during the winter months at least, the Douglas fir, cedar and hemlock type is preferred by martens above the other timber types, and that mature fir (*Pseudotsuga*) is also suitable habitat. Two martens were caught in strips of immature Douglas fir between alder thickets. Lodge pole pine does not appear to be such suitable habitat. These findings are similar to those of Marshall (1942) who states that fir and Douglas fir-spruce types were the most used and that the lodge pole pine type is used while moving between fir and spruce types. Not many traps were set in the rocky bluffs, and none was set in the alder and willow type, because track evidence indicated that only very few martens venture into these cover types.

The Ontario data indicate that martens apparently frequented cedar swamps more than other habitats in the study area. This is possibly the result of food concentrations there and the location of such swamps close to lake and stream shores, along which the animals seem to prefer to travel. Mixed coniferous-deciduous stands seem to be less preferred, and mature black spruce-jack-pine stands least desirable. The latter habitat is notoriously poor for most wildlife, especially when it is boggy.

Both studies seem to indicate (see Figs. 1 and 2) that martens may travel by preference close to stream beds and lake shores, which agrees with the findings of Marshall (1942). However, as practically all trapping took place close to streams and lakeshores, these findings are far from conclusive.

SUMMARY

Marten movement studies can be undertaken successfully by using live-traps, as a considerable percentage of the population can be recaptured. Although evidence is not conclusive, records indicate a tendency among martens to occupy a home range or foraging circuit. There is some indication that animals transplanted over a distance varying from one to twelve miles tend to return to the place where they were first captured.

In both study areas movements are apparently mainly restricted to a territory close to the main watersheds. Certain timber types appear to be more

TABLE 3.—TRAPPING SUCCESS IN THE MAJOR TIMBER TYPES

Timber Types:	No. Trapsites where martens were caught:	No. Trapsites where no martens were caught:
Washington		
Mature fir (*Pseudotsuga mucronata*)	8	18
Fir, cedar and hemlock (*Tsuga heterophylla*)	10	13
Dense immature fir (*Pseudotsuga mucronata*)	2	5
Lodge pole pine (*Pinus contorta*)	1	5
Swamp area with mature cedar (*Thuja plicata*)	1	4
Rocky bluffs with scattered fir and pine (*Pinus ponderosa*)	0	3
Alder (*Alnus sinuata*) and willow (*Salix sp.*)	0	0
Ontario		
Mature mixed stand of aspen (*Populus tremuloides*)		
White birch (*Betula papyrifera*), white spruce (*Picea glauca*), and jackpine (*Pinus banksiana*)	4	45
Mature black spruce (*Picea mariana*) and jackpine	2	28
Swamp with mature cedar	7	12

attractive to martens than others, possibly because food and cover are more amply available. In the Washington study area the fir, cedar and hemlock type seems to be preferred, while in the Ontario area the cedar-swamp type is most utilized.

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OBITUARIES

J. SOUTHGATE HOYT

John Southgate Yeaton Hoyt, son of the late Margaret Y. Hoyt and Dr. W. D. Hoyt, died of cancer at the Memorial Hospital in New York City on June 1, 1951 after a prolonged illness. He was born in Baltimore January 13, 1913.

"South", as he was called by his many friends, was best known for his studies and publications on the Pileated Woodpecker, a female of which he kept alive in his home for nine and a half years. He took his B.S. degree from Washington and Lee in 1938 and his Ph.D. from Cornell in 1948, and during the year of his death was assisting Professor Arthur A. Allen in the Laboratory of Ornithology at Cornell as Extension Lecturer and Radio Program Leader, as well as preparator.

During the summer months, from 1941–50, he and his wife, Sarah Foresman Hoyt, to whom he was married in 1942, directed the Natural History studies at Cold Spring Harbor, where they were much beloved by the children, as well as the faculty. Together they did a great deal of bird-banding and helped organise bird clubs and natural history societies; and served as leaders of scout organizations, even during the war years, when they both served as medical technicians, first at Stark General Hospital in Charleston, South Carolina, and later in Kennedy General Hospital in Memphis, Tennessee.

Dr. Hoyt became a member of the Wildlife Society in 1939. He was also affiliated with the American Ornithologists' Union, the Wilson Club, the Tennessee Ornithology Club, the Virginia Ornithology Society, the Cooper Club, the A.A.A.S., and the American Nature Study Society, and he will be missed by a host of friends, to whom he was always very helpful.

He is survived by two brothers, Robert and William D., Jr. and by his wife, who is carrying on some of their mutual projects.—*A. A. Allen.*

PAUL BONNOT

Paul Bonnot died very suddenly on August 1, 1951, at Bodega Bay. At the time, Mr. Bonnot was engaged in an abalone survey of the Northern California coast, and had recently commissioned a fully-equipped diving boat with which he was pursuing the study.

Following graduation from Stanford University in 1923, Mr. Bonnot first joined the Fish and Game Commission in 1925 as a warden. He soon transferred to biological work and followed this field as a marine biologist for the Bureau of Marine Fisheries until the time of his death.

Mr. Bonnot's active career was noteworthy for the variety of subjects encompassed. His research on oysters led directly to the development of the oyster industry of Morro, Drakes, Tomales, and other California bays. His most intensive work was on the abalone fishery, and most of our knowledge of this valuable mollusk has come from his research. In the course of the abalone work, Paul probably did more deep sea diving than any other biologist. The extent of his other shellfish work is reflected in numerous publications on shrimps, clams, and mussels. He also conducted research on marine algae, which included underwater observations of the agar resource.

It seems far cry from shellfish to marine mammals, but Mr. Bonnot was also an authority on sea lions and seals. His research in this field included numerous counts of the animals on the rookeries. During an aerial census several years ago, a Navy blimp crashed at sea and Paul and his companions spent over an hour in the icy waters off Cape Mendocino before their rescue by the lightship crew.

Paul's enthusiastic attitude toward his work was expressed in a conversation with his wife a few weeks before his death, when he said, "If I had my life to live over again, I would choose exactly the job I have."

The sincere sympathies of all who shared Paul's work on behalf of California's fish and game resources are extended to Mrs. Bonnot and his family.—RICHARD S. CROKER, *Chief, Bureau of Marine Fisheries, San Francisco, California* (*Prepared originally for publication in California Fish and Game*).

REVIEWS

American Resources, Their Management and Conservation. Whittaker J. Russell and Ackerman, Edward A., xi+497 pp., 76 maps, charts and illustrations. Harcourt, Brace and Company, New York, 1951. $6.75.

This is a first-rate college-level textbook on natural resources. It fills an important need in the comprehensive course on conservation for the general student. The dual authorship has avoided the pitfalls of multi-authored texts: duplication, unequal treatment of different subjects and conflicting philosophy. They have admirably treated each phase of the resources field without serious gaps or errors, a difficult feat for two individuals to accomplish in so broad a subject matter area.

The authors have depended entirely upon data to illustrate the text—mostly given in maps and charts. Possibly this is the best way to get across the vast amount of information to the student but this reviewer would prefer to have a sprinkling of photographs along with the bone-dry line illustrations.

Organization of the book is in 26 chapters, grouped into seven sections. An introduction considers the world conservation problems, the nature of resource deterioration, the relation of resources to human populations, and the United States situation. Then follow five "Parts" covering, in order: Cultivable Land, Grasslands and Forest Lands, Water Resources, Minerals and Their Uses, and Recreational Resources and Fish and Wildlife. A final section, "Conclusion", is sub-titled, "An American Citizen's Guide to Conservational Resource Management."

In most respects the treatment is up-to-date. Such modern subjects as soil conservation districts, land use capabilities, forest regulations, the Hoover Commission resource recommendations, valley authorities are examples and illustrate that the authors have kept abreast of recent developments. For the most part these matters are clearly outlined but some errors and omissions occur, as where they say, "the Soil Conservation Service and *its* soil conservation districts . . ." (p. 458), and the bare mention of atomic energy and the minerals involved.

Readers of this *Journal* will be particularly

concerned about the treatment accorded the wildlife resources. Probably this is the most inadequate of the sections but still a reasonably good job has been done. In point of space used, Part V gives 18 pages to "Wildlife of Land and Stream", and 17 each to "Marine and Great Lakes Fisheries" and "Resources of Scenic Value." Although this is obviously skimpy, it is not the full coverage. The authors deserve commendation for the attention given to wildlife resources throughout the book in connection with topics other than wildlife itself. The relation of wildlife to such subjects as land use capabilities, drainage, strip mining and pollution are covered in the chapters that treat these subjects and will serve to illustrate the point.

After discussing "The Wildlife Problem", some attention is given to wildlife economics and then the technical subject matter is covered in a listing of "Conservation Measures." While these are comprehensive, most attention is given to "Preservation of Natural Areas", "Refuges and Sanctuaries" and "Restocking", while habitat problems and harvest control are relatively slighted.

The final chapter, "An American Citizen's Guide", is especially significant. It attempts to bring the resource conservation problems down to the point of personal concern and action for every citizen. In so doing the authors reveal more of their own philosophy than in the subject matter chapters.

They begin by stating the objective of resources conservation to be, ". . . the maximum comfort, security, and happiness of all individuals in our society" (which seems to me to fall short of the major point, namely, the preservation of an adequate resource base for future generations of mankind). It then appraises our present situation—some gains, but much more needing to be done. The citizen may exert his influence in three ways—personally avoiding waste, supporting governmental conservation action, and applying "social pressure" which discourages waste by others. To do this he needs standards of judgment—for which the authors offer their own recommendations. These fall into eight problem fields: food production; industrial minerals; energy resources; wood production; water resources; recreational facilities (the nearest reference to any consideration of wildlife resources in this citizens' guide); regional instability; and, aid in developing foreign resources.

In developing these categories, the matter sometimes becomes quite complicated and may not be entirely satisfying to the citizen seeking guidance. The separate developments suggested may not harmonize. For example, the development of soil conservation districts and the valley authority have not been compatible in the Tennessee Valley. Some are quite nebulous, as, "More efficient management of the country's food-producing capacity, duly considering the efficiency of the several alternative methods of conservation and development." Some may be socially or politically unpalatable to many, such as governmental control of forest cutting and expansion of foreign aid in furnishing food supplies and in developing resources.

The authors point out the difficulties in achieving a national and unbiased view on resources policies. They point out, as almost anyone would agree that our governmental house is not all in order as regards natural resources. They advocate, ". . . an organization within the federal government which will be equipped to provide full and impartial technical review of all resource development and conservation programs or proposals . . ." Whether or not such a new agency could achieve unity and efficiency of government work in resource conservation is at least debatable. It is not yet achieved among some groups of agencies now within a single department. After all, conservation policies are political in nature whether we like it or not and there is apt to be a continuing variance of viewpoint both regarding policies and how they are carried out.

The *Citizens' Guide* is an interesting try at reconciling the facets of resource management but it may well raise as many questions in the reader's mind as it resolves.

This book should find wide use in the growing number of colleges that are presenting courses in national resources conservation.—FRANK C. EDMINSTER.

Game Birds and Mammals of California, a Laboratory Syllabus. By A. Starker Leopold. California Book Company, Berkeley. 125 pp. 29 plates, 22 figures. 1951. $3.00.

The scope of this laboratory study-aid is America-wide, focussing on California. It includes many economically important predators and rodents and omits certain game species no longer important, such as the shorebirds.

Printed on one side of good quality paper with cardboard cover and spiral binding, it will serve as notebook as well as laboratory guide. The text is perhaps over-simplified for use in a wildlife course, although the introduction and the brief general discussions on waterfowl and deer, for example, are excellent. With a more concise style, life history data could have been made more complete, and the reference value of the work thus increased.

Each species is treated according to range, habitat, and "remarks." Remarks follow no consistent pattern, but cover habits generally. Differentiation of the sexes is omitted or poorly covered—a point of importance in even an elementary wildlife study. Avian nomenclature is not up to date according to the A.O.U. check list supplements.

The many illustrations are diagrammatic, those of mammals much better than those of birds. In many cases only diagnostic areas of plumage or pelt are detailed—a method more confusing than helpful. Scale is unfortunately omitted. A bibliography contains 36 titles.—OLIVER H. HEWITT.

Waterfowl and their Food Plants in Washington. By Charles F. Yocom. University of Washington Press, Seattle. xvi+272 pp. 48 pl., 63 fig., 47 tables. 1951. $5.00.

The author's objective in this study was to produce a reference volume of value to future research on waterfowl in Washington. In this he has succeeded well.

More than half of the volume is devoted to a report on waterfowl status and distribution in relation to available habitat in Washington, to data gathered chiefly in a two-year preliminary survey of waterfowl production, and to brief, general reports on Washington's problems regarding sex ratios, diseases, harvesting and management. For example, the chapter on management comprises a three-page outline of federal and state waterfowl refuge projects plus a map and four photographs.

The remainder of the work consists of an analysis of waterfowl food habit studies based on 238 stomachs taken in various seasons, and a review of 19 families of food and cover plants important to waterfowl in Washington. Practical keys, distribution maps and very excellent illustrations by the author are provided for 126 of the more common plant species.

While this latter section will be of value to waterfowl workers over a wide area of the northwest, one-half of the work is local in scope and usefulness. One may question, therefore, the desirability of publishing these sections together in book form.

Fifty-six half-tones are included, of which eight have little bearing on the subject; also, eleven are repetitious; for example, there are six figures of Canada goose nests, where one would suffice. These add to the cost of the volume without contributing to its value.

Also questionable is the propriety of a university press in advertising that "Here you have in one book a full story of waterfowl. . . . Most of the study applies to all of North America. . . ." The work might have been published more appropriately as a state game commission bulletin.—OLIVER H. HEWITT.

The Dusky-footed Wood Rat. By Jean M. Linsdale and Lloyd P. Tevis, Jr. University of California Press, Berkeley and Los Angeles. 664 pp. 1951. $7.50.

This is one of the most comprehensive reports to appear on any of our American mammals. It is based on ten years of observations on and in the vicinity of the Hastings Natural History Reservation, California. The material is presented in ten chapters: Introduction, Habitat, Houses, Animal Associates, Behavior, Food, Reproduction, Morphology, Population, Conclusions. Naturally, certain sections are stronger than others, but the reviewer detected no major omissions. The many excellent figures and the extensive tabular material are of considerable aid.

Space does not permit comment on all sections but the following illustrate the completeness with which the authors treated their subject. Under Animal Associates they list 9 protozoans, 3 tapeworms, 3 roundworms, 1 sucking louse, 1 warblefly, 12 fleas, 5 ticks,

and 11 mites as parasites associated with wood rats on the Reservation. Quantitative figures are given and the effects of parasitism are evaluated in some instances. Information on dispersal of young is especially good, including specific examples and discussion of causes.

Despite the general high quality of the work, there are certain features which detract from the general value of the book. It appears that the authors in their effort to be thorough had a tendency to include too many minutiae with insufficient summarization and interpretation. Chapter III, Houses, is a typical example. The authors dismantled a series of wood rat houses which provided the basis for descriptions of 14 as to location, size, entrances, materials, etc. Some are described in more detail than others. They also include a number of examples of maintenance on individual houses that were not dismantled but observed from time to time. Still more information is presented under "Analysis of a Community." In this section the histories of 52 houses are traced over a seven-year period. In addition to a history of occupants, there is much information on physical characteristics, maintenance, deterioration, etc. There are other cases of needless repetition.

A disconcerting feature is the quite frequent habit of including thoughts that have nothing to do with the subject at hand. For example, on page 69, the authors, in describing the construction of a house, tell of finding the occupant. To the reviewer this seemed sufficient, but they inserted the sentence, "The rat squealed when captured." On page 372, the authors describe the breeding condition of a female rat and remark that "On this occasion, after the rat was handled and returned to the trap, she rattled her tail against the sides of that container."

In the preface it is pointed out that the authors made use of various wood rat reports but no effort was made to compile and cite the information contained in them. The reviewer feels that they also did not particularly concern themselves with other small mammal studies of somewhat similar scope. Reference to the literature at several points would have made the book more useful. For example, on page 267, the authors state "Means were developed to identify by histological characters the samples of various types of food eaten." The reviewer immediately wondered what the technique consisted of and whether it was similar, for example, to the one described by Baumgartner and Martin for identification of stomach contents of squirrels (Jour. Wildl. Mgt. 3(3): 266–268).

Although the methods of presentation could have been improved, the authors are to be congratulated for their excellent job of compiling the mass of data presented. The book, from an overall standpoint, is an outstanding one with which students of mammalogy should be acquainted.—DON C. QUIMBY, *Montana State College, Bozeman, Mont.*

Älgen, Studier, jakt och vård. By Folke Skuncke, P. A. Norstedt and Soners 1949, Forlag/ Stockholm, Sweden. 400 pp. Kr. 40 in paper, 46 bound. (About $7.80 and $10, respectively).

In the past few years Sweden has apparently maintained one of the highest moose populations for any area of comparable size in the world. According to R. Lubec (1947, Algstatistiken. Enliten Korrigering. Svensk Jakt, Svenska Jägareförbundets Tidskrift, Stockholm. Arg. 85, NiR pp. 72–73.) 11,334 moose were killed in 116,323 square miles (not Swedish square miles) of forested area. A report in a later issue of the same publication (1949) shows a preliminary tabulation of the kill of 14,912 moose in 1948 (roughly one moose for an average of every 7.77 sq. miles). Skuncke estimates that the total winter population for 1945 was close to 39,000 animals. The 1948 kill possibly exceeded the legal kill for the entire North American continent for that year. This recent high population is apparently unique for Sweden, increasing almost steadily from a harvest of less than 4,000 in 1928 with only one period of decline (1942–1945). Small, relatively thickly populated Sweden has undoubtedly gone further than any country in the world in management of moose. In fact some think almost too far, with respect to building up the population, because of extensive damage to reforestation. Sweden also leads in a scientific understanding of moose as exemplified by many sound publications.

The present volume seems to emphasize this point. Folke Skuncke is described by the publishers as a crown forester, an office which

includes game management duties. He has published three other major works on moose (1934, 1937 and 1940). His 1937 work (translated "Everything about the hunting of the moose") was a forerunner of the present work, the latter constituting a revision and enlargement of scope. This book, based on 40 years experience, states in the introduction that it is not an attempt to be a monograph on the moose, nor does it claim to add anything of scientific importance. It also does not claim to interest any other than 'friends of nature.' Its chief objective is a hope 'that it, in some small measure, will help to a wise conservation of our moose population.'

A so-called "popular" work written principally for the hunter and naturalist, this book sets a standard that is not approached by the average "popular" work on this continent in the wealth and value of its contents. Similar contrasts are found in the quality of articles published in *Svensk Jakt* the Swedish hunting magazine published by the Swedish Hunter's League compared to that of our own sportsman's magazines.

The first part of Älgen ('The moose, studies, hunting and conservation') contains a history and a review of the distribution of the moose. The second part is devoted to the behaviour and life history. The third part, 'the hunt and its basis' is the longest part of the book (pp. 85–302). The fourth part discusses general regulations, selection of animals to be shot and the treatment of wounded and sick animals. In the fifth part the author reaches his major conclusions, presents his ideas on rate of reproduction, the esthetic and economical values of moose to Sweden and suggests a moose conservation and management program.

To one interested in North American moose this book presents a "gold mine" of information on life history and ecology that simply does not exist in North American literature. Unfortunately it is frequently difficult to determine what data are original and what have been taken from other authors. In certain cases it has seemed advisable to refer back to original authors, when sources are known. It is most unfortunate that no bibliography or index is present.

One outstanding, and apparently original, contribution concerns the data on dressed weights of over 2,000 animals of designated age. Unfortunately there is some confusion concerning a part of the sample as to whether or not the butcher had or had not removed the shot damaged meat before weighing. He presents live weights of 637 known age animals from one general area and provides a growth curve for bulls, cows with calves and cows without calves. At present it seems doubtful if such extensive data could ever be gathered in North America.

The section on behaviour and life history contains important discussions of such things as the effect of the soil's pH value on moose, general ecology, behaviour, senses, territoriality, seasonal activities, scatology, diet, antler development, breeding habits, diseases, parasites and abnormalities. Tucked away in a chapter on individual selection while moose hunting, is an important discussion of aging animals by teeth, some original, some by other authors.

The section on conservation and management (fifth part) should be a "must" for anyone interested in this subject. It is a sound discussion of practical management problems. It covers such points as standards for hunters, permits for firearms and ammunition, liability or hunting insurance, control of moose damage, habitat improvement, chemical supplements to diet, reduction by special licenced hunters, rotation of hunting areas, shooting of cows, calves and bulls and many other important aspects of management. The author points out that where there is a closed season on cows the number of bulls shot decreases, at times, by as much as 50% of normal. He sums up his discussion of this point (p. 308) by stating in his opinion, the practice of a closed season on cows is most nearly analogous to handing of firearms to a blind person. 'This practice has little in common with true moose conservation.'

The book contains several inconsistencies and even a few contradictions, some of them obviously caused by a great lapse of time between the time various sections were written.

As a whole, this book greatly exceeds the modest contribution claimed for it by its author. It is only to be regretted that it is not widely available in the English language.—RANDOLPH L. PETERSON, *Royal Ontario Museum of Zoology and Palaeontology, Toronto, Ontario.*

A Reproduction Study of Northern White Cedar, by Thomas C. Nelson, Game Division, Department of Conservation, Lansing, Michigan. 1951. 100 pp., 42 figures, 34 tables, appendix.

Wildlife technicians located within the range of northern white cedar and who are concerned with management of the white-tailed deer will find this 100-page bulletin of considerable interest. The author conducted an investigation of many of the ecological factors pertaining to cedar reproduction. Laboratory studies were carried out in conjunction with field observations on the various phases of the problem. Results should prove of value to the game manager or the forester who may be endeavoring to increase production of cedar. This investigation confirms, to a large extent, the more general findings and surmises of previous workers—especially of Maki in Minnesota and Curtis in Maine; but considerable new information was brought to light.

The research was conducted under two general headings: (1) germination and initial reproduction and (2) survival. Studies of the former were concerned mainly with seed viability, light, soil acidity, types of germinating media, temperature, and moisture. Principal mortality factors were desiccation, and browsing by deer and snowshoe hares. It was concluded that reproduction by seedlings resulted in straighter trees of most importance to foresters while vegetative reproduction yielded the maximum of foliage for deer browse. Management of cedar, whether for commercial or wildlife purposes, was found to involve rather simple but seemingly effective silviculture practises. Cedar reproduction was greater when slash was scattered rather than piled and burned. Light cutting (or browsing) favored cedar reproduction, whereas heavy cutting resulted in considerable invasion of alder and balsam fir. The findings appear to have valuable application on small units of land, but there may be some doubt as to their practicability on a widespread basis, where a major deer problem exists.

Principal criticism by this reviewer is not with the subject matter but with the manner in which it is presented. It is extremely difficult reading. Game or forest administrators could find much "meat" in the bulletin but probably will not go through the laborious reading necessary to obtain this information. It is unfortunate that the author did not organize his text more carefully and simply, and did not present his material in words that busy administrators could understand. It is the administrator, not the trained technician, who must put research findings into practice. For that matter, many technicians likewise will have considerable trouble in digesting the mass of data contained in the bulletin. These comments apply to the text primarily, but an overabundance of tables, charts, and graphs—some of which are not very clear—add to the reading difficulties. Since a 7-page appendix is presented anyhow, it would seem better to have enlarged this by including many of the tables and graphs now interspersed through the text. It was disappointing, in a publication of this length, to find so brief and vague a statement as to the scope and duration of the study. The exact State-college participation in the investigation is not clear. Although the author has been very careful in his interpretation of data, there are a few instances where the quantitative data were few; for example only four milacre plots were established to measure survival and mortality.

The foregoing criticisms are relatively minor, however, as far as the cedar investigation is concerned. It is an extensive study with opportunities for useful applications. The author, his advisers, and his sponsors are deserving of much credit.—HOWARD L. MENDALL.

Die Problematik der Heckenlandschaft (Fencerow problems) *Erdkunde* vol. 5 no. 2. pp. 105–157. (1951). Geiger, R. Der künstliche Windschutz als meterologisches Problem. pp. 106–114. Wendt, H. Der Einfluss der Hecken auf den Landwirtschaftlichen Ertrag. pp. 115–125. Tischler, W. Die Hecke als Lebensraum für Pflanzen und Tiere unter besonderer Berücksichtigung ihrer Schädlinge. pp. 125–132. Hartke, W. Die Heckenlandschaft. pp. 132–152. Troll, C. Heckenlandschaften im maritimen Grünlandgürtel und im Gaüland Mitteleuropas. pp. 152–157.

As the economic value of fencerows to the farmer is usually considered debatable in this country and fencerows are rapidly disappearing

despite protests of wildlife managers, a short review of a symposium recently published in Europe may be in order. The contents of two of the papers, those by Wendt and Tischler, appear to be ammunition for the game manager. Since the papers are probably not readily available to many ecologists, I will give here an outline of their contents rather than a critical review.

Unfortunately the German term "Hecke" is a vague one, as it may mean a hedge, a fencerow, or a windbreak with or without undergrowth (although the presence of undergrowth is always recommended). Wendt does not explain to which type he is referring nor does he give its plant composition.

According to Wendt, whose paper is a survey of the literature, fencerows change the microclimate and with this the soil moisture is increased and evaporation decreased. Water run off is slowed, and more water moves into the soil, improving soil structure. Conditions that favor cultivated plants are improved by fencerows, with particular advantages to moisture loving plants. The exact increase of harvest is hard to foretell. Experiments over a decade in Havelland (East of Berlin) (17.4 km [10.8m] of fencerows on 367 ha [910 acres]) showed that cereals grown under protection of fencerows had wider, darker leaves, and received more dew than plants which were grown under similar conditions in the open. On the other hand, the unprotected plants were frequently severely damaged by blowing sand. The average amount by which the yield of the protected area surpassed that of the control was about 15% of the harvest. The results of many experiments made in Russia show winter wheat yields have been increased from 16.5 to 28.3 dz/ha, rye from 16.5 to 29.7, oats from 18.7 to 22.2 and alfalfa from 31.9 to 61.9 dz/ha. In years of drought the difference in harvest was found to be as high as 300% in Russian wheatlands. The effect of fencerows was most beneficial to brome grass, alfalfa and corn, less so to winter wheat and barley and still less to rye and oats. Fencerows may not be of advantage to the culture of oats. Many years of experience in some areas of Russia point to an average increase in yield of 50 kg/ha (45 lbs/acre) if the protected areas were not larger than 100 ha (248 acres). Protected pastures were found to become green earlier in the year.

Fencerows also reduced water and wind erosion. Poplar should not be planted in fencerows since it removes nutrients from the soil and thus may reduce yields.

It seems advisable to confine the roots of the fencerow plants either by digging a trench alongside the row, or by planting the row on a low bank.

The paper is well illustrated with graphs, some of them showing the decrease of yields with distance from fencerows. There is a bibliography.

Tischler's paper is based on his extensive studies of the fauna of Schleswig-Holstein fencerows. Tischler found that while many pests will overwinter or seek refuge in hedges, removal of the fencerows may force other animals into cultivated fields where they become pests. The fauna of fencerows is very rich, particularly in predatious species and parasites (parasitic insects and insectivorous birds being predominant). The parasites may need intermediate hosts which are easily found among the abundant fauna of fencerows, but they will not necessarily follow their hosts into the fields. Impoverishment of the fauna after removal of hedges may result in decreased environmental resistance to field pests, and consequently, in an increase of the pest population. Fencerows, however, can not be considered universal cures against pests.—HERBERT W. LEVI, *University of Wisconsin, Wausau Extension Center, Wausau, Wisc.*

RECENT PUBLICATIONS

Papers on Game Research, Nos. 6 and 7, Finnish Foundation for Game Preservation, Game Research Institute, Helsinki, P. Rautatiek. 13, Finland. 1951.

No. 6 contains a series of seven papers concerned with diseases and parasites in game animals, five of them by T. Lampio. No. 7 is "On the sex ratio, sex differentiation, and regional variation in the marten in Finland," also by T. Lampio.

Bird Life of Virginia. By Joseph J. Shomon. Commission of Game and Inland Fisheries, Richmond, Virginia. 88 pp. illus. 1951. $.25.

A concise, useful publication for beginners in bird study and conservation. Includes chapters on studying birds, the value of birds, conservation, and appendices presenting a check list of Virginia birds, a list of state birds, and a brief bibliography. There are many photographs in black and white, a cover painting in color by Walter Weber showing a group of cardinals on flowering dogwood, and a series of center inserts in color depicting about 120 species of birds. Very well designed to stimulate bird study and conservation.

American Weasels. By E. Raymond Hall. University of Kansas Publications, Museum of Natural History, Lawrence, Kansas. Vol. 4, pp. 1–466. 1951.

A comprehensive systematic treatment of the weasels of North and South America, which will be of interest to wildlife ecologists, as well as taxonomists because for each species material is presented from a thorough search of the literature on natural history, enemies, food, reproduction, populations, etc.

Shrub Plantings for Soil Conservation and Wildlife Cover in the Northeast. By Frank C. Edminster and Richard M. May. U.S. Department of Agriculture Circular No. 887. Superintendent of Documents, Washington, D. C. 68 pp. 1951. $.30.

"This circular sets forth the results of field tests on over 100 species of shrubs which have been planted under different climatic and soil conditions for conservation purposes in various parts of the northeast. Instructions are given for the successful planting and care of many of these shrubs."

BRIEFER ARTICLES

A MARKING TECHNIQUE FOR RING-NECKED PHEASANTS

Within recent years new, or modifications of former, techniques for marking game birds have facilitated the study of bird behavior and movement. During the winters of 1948–49 and 1949–50, while engaged in marking the rectrices of pheasants with paint, the writers noted that DuPont Duco Household Cement provided an excellent base for the application of a fast-drying, colored lacquer. The use of various paints on feathers has been limited by the absorption of the materials by the feathers and the length of drying time. Adequate marking, which required a minimum of two coats of paint, necessitated excessive handling of each bird and was time consuming, especially in marking more than ten birds.

The marking technique utilized was as follows: Pheasants were transferred in groups of four or five in burlap sacks from the traps to a sedan delivery truck, a convenient field shelter in which to mark birds in sub-zero weather. To facilitate handling, an individual bird was taken from the burlap bag and placed in a smaller sack, so that the tail feathers protruded. The outer inch of one or two center rectrices was cut off with a pair of scissors as a precaution against the tail feathers freezing in the snow and as an additional means of field identification. Then, each of the shortened rectrices received a coat of DuPont Duco Household Cement, which dried in about one minute, and over that a coat of either red or yellow DuPont Duco auto lacquer, which dried sufficiently to release the bird in about two minutes. These feathers were distinguishable up to a distance of about 400 yards with an eight-power binocular from about March to June of each year when the spring dispersal studies were terminated. In addition, each bird was marked with a colored, plastic band and an aluminum, butt-end, pheasant band.

A total of 770 pheasants were marked during the two years that this method was utilized. Eight feathers (one percent) were found—five in retrapping operations and three in subsequent field studies. In contrast to this method, 43 feathers (14 percent) of 303 tail feathers marked by the application of a previously painted feather to a "host" tail feather of a pheasant (Edminister, 1938, Jour. Wildl. Mgt. 2(2): 55–57) were found—33 in retrapping operations and 10 in subsequent field work.

Experimentally, 20 game-farm pheasants, marked with this technique and identified with aluminum butt-end pheasant bands, were released in a five-acre holding pen at the Iowa State Conservation Commission Game Farm, Boone, Iowa, on September 17, 1949. Of the 16 birds examined in February, 1950, five (25 percent) still had markers in good shape; eight (40 percent) showed the outer edges of the web of the rectrices to be slightly pecked; three (15 percent), although badly pecked, were readily distinguishable with the bird in the hand.

The technique has two disadvantages: (1) some birds, as indicated both in field and game farm studies, pecked the web of the painted rectrices, and (2) the marker was lost during the postnuptial moult.—Edward L. Kozicky and Henry G. Weston, Jr., *Iowa Cooperative Wildlife Research Unit, Iowa State College, Ames, Iowa.* (Jour. Paper No. J-1923, Iowa Agricultural Experiment Station, Ames, Iowa, Project 497.)

Accepted for publication March 30, 1951.

OBSERVATIONS OF INFILTRATION RATES AND SEDIMENT PRODUCTION ON BIG GAME RANGES

During the late summer and early fall of 1949 a crew of technicians from the Flood Control Surveys Division of the Intermountain Forest and Range Experiment Station made a series of infiltration runs on big game range in the Teton National Forest in Wyoming. The first group of investigations was made on heavily grazed range used exclusively by elk near the Upper Slide Lake in the Gros Ventre drainage. The second group was made on heavily grazed range used predominantly by elk, occasionally by deer, and in very slight amounts by domestic livestock near Camp Creek in the Hoback drainage.

Comparable infiltration runs were made on both good and poor grass sites inside and outside of totally protected plots (big game exclosures) that had been established on each

TABLE 1.—INFILTRATION CAPACITIES AND SEDIMENT PRODUCTION INSIDE AND OUTSIDE OF GROS VENTRE BIG GAME EXCLOSURE, TETON NATIONAL FOREST, WYOMING, 1949 [1]

Location	Vegetal Cover [2] (percent)	Bare Ground [3] (percent)	Infiltration Capacity [4] (in./hr.)		Sediment Production [5] (lbs./acre)	
			Dry run	Wet run	Dry run	Wet run
Inside enclosure:						
Good site	50	38	2.78	2.23	31.7	25.0
Poor site	12	73	2.10	1.20	35.8	31.4
Outside exclosure:						
Good site	27	58	1.80	1.18	157.1	84.3
Poor site	8	79	1.40	1.09	99.6	95.6

[1] Soils derived from cretaceous shale and sandstone; light-textured and deep.
[2] Exclusive of litter.
[3] Exclusive of erosion pavement.
[4] Rate of water intake by the soil profile 45 minutes after beginning of run. Second (wet) run made approximately 24 hours after first (dry) run.
[5] Total during first 36 minutes of run.

TABLE 2.—INFILTRATION CAPACITIES AND SEDIMENT PRODUCTION INSIDE AND OUTSIDE OF HOBACK BIG GAME EXCLOSURE, TETON NATIONAL FOREST, WYOMING, 1949 [1]

Location	Vegetal Cover (percent)	Bare Ground (percent)	Infiltration Capacity (in./hr.)		Sediment Production (lbs./acre)	
			Dry run	Wet run	Dry run	Wet run
Grass Plots						
Inside exclosure:						
Good site	29	11	4.25	3.80	30.6	71.1
Poor site	21	64	1.43	1.32	(2)	(2)
Outside exclosure:						
Good site	25	66	1.10	.60	918.0	1140.7
Poor site	11	80	[3] 3.72	.90	(2)	(2)
Browse Plots						
Inside exclosure	80	5	6.65	5.97	(4)	26.7
Outside exclosure	50	15	5.00	2.15	20.4	41.2

[1] Soils derived from Wasatch conglomerate; heavy-textured and deep.
[2] Data not available. Ocular estimates indicated far higher rates of sediment production than on corresponding good site.
[3] Rate of infiltration high due to fissures caused by sun-baking.
[4] Sediment production too small to measure.

range in 1938. On the Hoback range additional runs were made on average browse sites inside and outside the exclosure. The study areas were subjected to applications of artificial rainfall at intensities of about 6 inches per hour by means of type FA infiltrometers.

As Tables 1 and 2 show, the infiltration capacity was greater and the sediment production was less inside the exclosures where the plant-soil complexes had been protected. The protected browse site had the highest infiltration capacity and the smallest amount of sediment production of all sites studied (Table 2). These observations indicate that management of big game range to reduce overutilization of the vegetation may result in better watershed conditions through site stabilization and increased infiltration capacities.—MERLE H. TIGERMAN, *Intermountain Forest and Range Experiment Station, Ogden, Utah.*

Accepted for publication April 16, 1951.

A CULTURAL MEDIA KIT FOR FIELD USE

In small laboratories, there is always the problem of keeping bacteriological culture media available when there is no constant need. After preparation, the tubed media may be stored in the refrigerator for several weeks. Unless the tubes are properly sealed or placed in a sealed container, there is evaporation which results in drying until the media are no longer useable. This loss is expensive in both time and materials. To avoid this, we have used the following procedure:

After the media have been tubed, two tubes of each of five (nutrient agar, chocolate agar, Endo agar, Loffler's blood serum and cooked meat media) are placed in a plastic or cellophane bag. The plastic bags are sealed with a rubber band while the cellophane bags are sealed with heat. The plastic bags are superior to the cellophane because they are less fragile.

The bag and tubes are then placed in a standard sized waxed freezer carton, 4 x 8 x 1¾ inches. This is a convenient size for the tubes and offers considerable protection while in the field. The boxes are then placed in a deep freezer. We have used a four cubic foot freezer loaned to us by the International Harvester Company, Cheyenne, Branch. This size freezer will hold 90 kits.

After 28 months in the deep freezer, there has been little change in the media. The changes noted are a slight shrinking which makes for more fluid on slants and grainy appearance in the nutrient agar slant. Also there has been a darkening and slight wrinkling of the Loffler's blood serum. None of these changes have impared the nutrient qualities in so far as we can observe.

When a field trip is planned, one or more of these kits are taken along. If the kit was not used, it is again placed in the freezer. Some of the kits have been thawed and refrozen several times. This has not injured their quality.—RALPH F. HONESS AND KENNETH WINTER, *Wyoming Game and Fish Commission, Federal Aid in Wildlife Restoration Act-Project 33-R, Wyoming.*

Accepted for publication July 14, 1951.

RABIES IN BEAVER

On March 2, 1951, at 9:00 p.m., a beaver attacked a farm dog in a farmer's yard 8 miles south of Columbia, Missouri, the attack occurring within 25 feet of the farm house. The beaver inflicted serious cuts on the dog's throat and neck; when the farmer investigated the commotion in his yard, the beaver lunged toward him. Procuring a shotgun, the farmer promptly dispatched the animal. The beaver, a male weighing 31 pounds, was examined the following day by Dr. H. H. Berrier, Jr., of the University of Missouri School of Veterinary Medicine. Microscopic examination for Negri bodies in the Ammons Horn (hippocampus) tissue of the brain by Dr. Berrier positively established the presence of rabies infection.

A review of the literature and correspondence with the American Veterinarian's Association and with the veterinarian in charge of rabies investigations for the U. S. Public Health Service, reveals no record of rabies occurring in beaver. Since this appears to be the first case reported, it should be of interest to wildlife workers.

The incident occurred on an upland farming area. The nearest known concentration of beaver is approximately 8 miles away on the Missouri River. However, beaver sign has been noted on some of the permanent streams in the area, one of which runs within 2 miles of the farmstead. Beaver numbers have steadily increased throughout this area in recent years. —GEORGE K. BRAKHAGE, *Missouri Cooperative Wildlife Research Unit, University of Missouri, Columbia;* and FRANK W. SAMPSON, *Missouri Conservation Commission, Columbia, Missouri.*

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FUR SEALS PREYING ON BLACK-FOOTED ALBATROSS[1]

It has been stated (Miller, Condor, **42**: 229–238, 1940; Yocum, Auk, **64**: 507–523, 1947) that the Black-footed Albatross (*Diomedea nigripes*) is almost completely free from predators while at sea. Nevertheless, mammals other than man have been observed to attack these birds. On the night of April 5, 1949, the author was fishing with the aid of a light from the deck of the Scripps Institution vessel "Horizon." Two Black-footed Albatrosses were riding the surface at the outer edge of the lighted area, picking up the fishes that came their way. A seal was also feeding on these fishes (*Cololabis saira, Myctophum affine, Tarletonbeania crenularis*) beneath the surface. Twice it rushed at the legs of the birds, and finally drove them away. The next morning a seaman on watch reported having seen a seal pull an albatross under, and the bird did not reappear.

These observations were made at approximately 35° 44′ N. Lat., 128° 37′ W. Long. Since this position is about 300 miles from the nearest point of land, it is almost certain that the predator was the Pribilof fur seal (*Callorhinus ursinus*). Clemens, Hart, and Wilby (Analysis of stomach contents of fur seals taken off the west coast of Vancouver Island in April and May, 1935. Dept. Fisheries, Ottawa, Canada, 1936) have reported a Marbled Murrelet (*Brachyramphus marmoratum*) in a fur-seal stomach.—J. L. MCHUGH, *Virginia Fisheries Laboratory, Gloucester Point, Va.*

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[1] Contributions from the Scripps Institution of Oceanography, New Series, No. 566.

AN APPLICATION OF AERIAL PHOTOGRAPHY TO LAND-USE AND COVER MAPPING

The value of aerial photographs to wildlife research and management has been established. Leedy (Jour. Wildl. Mgt. **12**: 191–210, 1948) has discussed adequately their use, selection, interpretation and source. Among other suggested uses, he states, "Two important and widespread uses of aerial photographs are as maps and as aids in map making." Dalke (Jour. Wildl. Mgt. 5: 103-107, 1941) has suggested making tracings for base maps from aerial photographs or using the photographs directly in the field.

The use of aerial photographs in mapping has advantages as well as disadvantages. For mapping extensive areas the major advantages are: (1) the low initial cost of individual photographs and (2) the great amount of detail available. The major disadvantages are: (1) the relatively high cost of reproducing, in quantities, a final map containing the details available on aerial photographs and (2) the large number of individual aerial photographs needed for coverage of an extensive area which prohibits their direct use on a "practical" composite map.

These advantages and disadvantages are particularly obvious when attempting to prepare land-use and cover maps of counties. A desirable method of mapping such extensive areas should: (1) furnish detail, such as is available on aerial photographs, (2) be applicable to field use and (3) favor the economical reproduction of a final composite map.

A method that approaches the fulfilment of these objectives has been developed for use on a county land-use and cover mapping phase of a Tennessee Federal Aid Project. In brief, the method consists of using film positives of county aerial photo-indexes in conjunction with the "Ozalid process" to make maps. The maps are accompanied by supplementary information arranged in graphic or tabular form, e.g. forest and agricultural statistics.

The "Ozalid Streamliner," a machine that utilizes this process, is a product of Ozalid, Division of General Aniline and Film Corporation, Johnson City, New York. This corporation distributes a publication, "How to get the most value with Ozalid," which describes in detail the process and its applications. The process is a means of reproducing positive prints of maps, records, photographs and other items on papers, cloths, foils and films. It involves exposure of materials to ultra-violet light and dry development with ammonia vapor.

Continuous-tone photographs can be reproduced on special papers with a film positive of the photograph. The prints are grain free and can be made in sepia, black or blue. Such prints are relatively expensive; however, prints of aerial photographs suitable for field use can be made on a cheaper grade paper. These lack the high quality of tone and great detail available with the more expensive papers.

Of the materials tested the following appear to be suitable for making maps. Current prices for 100 sheets (18" x 24") are listed.

Ozaplastic **102** *Z*—detail and tone, does not crack when folded, price—$31.70

Ozalid Dryphoto **404** *D*—detail and tone, cracks when folded, price—$35.00

Dietzgen **241** *B*—suitable for field use, lacks the degree of tone and detail available with 102 Z and 404 D, price—$4.70

Dietzgen **244**—similar to 241 B, price—$11.70

The above materials were used with film positives of county aerial photo-indexes when preparing base maps used in cover-mapping a county. These film positives can be obtained from the Eastern Laboratory (Washington, D. C.) or Western Laboratory (Salt Lake City, Utah) of the Aerial Photographic and Engineering Service, Production and Marketing Administration at the current price of $3.50 per film positive (18" x 24"). County photo-indexes available from this agency, although containing individual photograph designations which obscure small areas, contain excellent detail considering their extensive coverage. In general, indexes compiled within the last few years are good uncontrolled mosaics. The number of photo-indexes per county vary depending upon the size and shape of the county —in Tennessee there are from 1 to 4 indexes per county.

Another machine, a B W Printer made by Charles Brunning Co., Inc., can be used to

reproduce (on Dietzgen Directo Paper No. 250, $5.69/100 sheets, 18" x 24") aerial photographs from film positives; however, the prints, although suitable for field use, discolor with age.

Additional information, e.g. game ranges, can be superimposed upon a print of an aerial photograph merely by attaching a sheet of drafting acetate, containing the desired data, to the film positive prior to exposure. India ink or pencil can be used on the acetate and any desired changes can be made easily on this medium. This method of superimposing information leaves the film positive intact for future use.

The reproduction of maps is not the only use of this process as it can be invaluable to wildlife administrators and technicians as a means of reproducing records at a minimum of time and expense. It should be stressed that the possibilities available with this process are difficult to explain in a manuscript; only by observing the completed materials can they be appreciated.

Acknowledgments are due W. H. Griffin, R. Roach and R. Robinson for the assistance they extended to the writer. — VINCENT SCHULTZ, *Tennessee Game and Fish Commission, Nashville, Tennessee.*

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FOODS OF SOME MIGRATORY WATERFOWL IN PENNSYLVANIA[1]

[1] Paper No. 57 from the Pennsylvania Cooperative Wildlife Research Unit. Fish and Wildlife Service (U.S. Department of the Interior), The Pennsylvania State College, the Pennsylvania Game Commission, and the Wildlife Management Institute cooperating.

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Acknowledgment is made to Dr. Ward M. Sharp, Leader, Pennsylvania Cooperative Wildlife Research Unit, under whose direction this study was conducted, and to Dr. P. F. English, Professor of Wildlife Management, The Pennsylvania State College, for advice and criticism. Mr. Roy T. Rutter and Mr. Marlin Haines of Millersburg, Pennsylvania cooperated in the collection of specimens. I am indebted to Dr. A. C. Martin and his associates of the Patuxent Research Refuge, Laurel, Maryland, for assistance in identifying unknown food items and for suggestions regarding the presentation of material in this paper.

INTRODUCTION

Pennsylvania as a whole provides poor waterfowl hunting; however, certain localities, by virtue of being situated on a sizable body of water, do provide considerable sport for the wildfowler. This report presents the results of a food habits study on a small series of waterfowl gizzards which was collected in such a locality. The objective of the investigation was to determine the kinds and amounts of food used by waterfowl while in migration through Pennsylvania.

AREA AND METHODS

The 1949 waterfowl season in Pennsylvania extended from October 21 to November 29. During this period the 54 specimens (Table 1) for this study were collected on the Susquehanna River near Millersburg, Dauphin County, Pennsylvania.

TABLE 1.—SPECIES AND NUMBER OF GIZZARDS COLLECTED

Common Name	Scientific Name	No. of Gizzards
Canada Goose	*Branta c. canadensis*	2
Common Mallard	*Anas p. platyrhynchos*	4
Black Duck	*Anas rubripes*	18
Baldpate	*Mareca americana*	2
Pintail	*Anas acuta tzitzihoa*	2
Green-winged Teal	*Anas carolinensis*	6
Wood Duck	*Aix sponsa*	1
Redhead	*Aythya americana*	1
Ringnecked Duck	*Aythya collaris*	1
Canvasback	*Aythya valisineria*	5
Scaup	*Aythya marila nearctica* and *Aythya affinis*	9
Bufflehead	*Bucephala albeola*	1
Ruddy Duck	*Oxyura jamaicensis rubida*	2
TOTAL		54

In this area the river is approximately three-fourths to one mile wide, and its normal depth averages three to four feet. Several large and many small islands and numerous "grass

patches" interrupt the wide expanse of water.

Knowledge of the dominant vegetation was gathered from field observations. River birch (*Betula nigra*) is the common woody cover on the islands. The ground cover beneath the birch consists chiefly of dewberry and blackberry (*Rubus spp.*), Virginia creeper (*Psedera quinquefolia*) and poison ivy (*Rhus toxicodendron*), while on the water's edge smartweeds (*Polygonum spp.*), wild millet (*Echinochloa crusgalli*) and other grasses and some sedges occur. Among the grass patches are pure stands of common three-square (*Scirpus americanus*) which have originated as invading communities on the sand and gravel bars.

Snails (*Goniobasis sp.*) are common on much of the river bottom.

The techniques used in the collection, preservation and analysis of the study material followed those of the U. S. Fish and Wildlife Service (Martin, 1949). Tabulation of data was by the aggregate volume method described by Martin, Gensch and Brown (1946).

DISCUSSION

Most of the gizzards contained little food material, although the specimens were collected at all hours of the day. The data are admittedly scanty, but may suggest local foods which are of importance during the migratory period.

The average volume of food in the 54 gizzards was only 1.9 cc. while the total content (including gravel) averaged 4.2 cc. The maximum volume of food recorded during the study was from a black duck which had 17.5 cc. and an additional 0.5 cc. of gravel. Three specimens contained no food, and seven specimens had only a trace of food. Mendall (1949) states that most of the duck stomachs examined in the Maine study contained less than 25 cc. of food. In his study the maximum volume was 83 cc. The presentation of data in most other waterfowl food habits studies follows the percentage by bulk or percent-volume method which fails to show actual volume of food taken by the various species. Pirnie (1935) examined more than 1,000 gizzards and found that over half were practically empty. No definite cause was attributed to the lack of food.

It is interesting to compare the relative quantities of food and gravel present in pond ducks (Anatinae) and the diving ducks (Aythyinae). In the pond-duck group, food

TABLE 2.—VOLUME AND PERCENTAGE OF FOOD PRESENT IN 50 WATERFOWL, SUSQUEHANNA RIVER, PENNSYLVANIA, FALL 1949

Vegetable Food	33 Pond Ducks cc.	%	17 Diving Ducks cc.	%
Muskgrass				
Chara sp.			1.2	16
Burreeds				
Sparganium eurycarpum			T	
Sparganium sp.	6.0	7	0.2	3
Pondweeds				
Potamogeton pectinatus			0.2	3
Potamogeton sp.	5.7	6	2.1	28
Rice Cutgrass				
Leersia oryzoides	T			
Witch Grass				
Panicum capillare	19.3	21	T	
Wild Millet				
Echinochloa crusgalli	0.2	0		
Cyperus				
Cyperus sp.			T	
Spikerush				
Eleocharis ovata	5.1	6	T	
Bulrushes				
Scirpus americanus	1.0	1	0.3	4
Scirpus acutus	0.2	0		
Scirpus fluviatilis	1.6	2	0.1	1
Scirpus robustus	4.0	5		
Sedge				
Carex sp.	2.1	2		
Cladium-Twig Rush				
Cladium mariscoides	0.1	0		
Blue Beech				
Carpinus caroliniana	T			
Ironwood				
Ostrya virginiana	T			
Dock				
Rumex sp.	T			
Smartweeds				
Polygonum lapathifolium	1.4	2	T	
Polygonum pennsylvanicum	3.4	3		
Polygonum sagittatum	0.1	0		
Watershield				
Brasenia schreberi	2.2	2	T	
Blackberry or Dewberry				
Rubus sp.	0.1	0		
Cherry				
Prunus sp.	T			
Virginia Creeper				
Psedera quinquefolia	T			
Watermilfoil				
Myriophyllum sp.			0.1	1
Beggar Ticks				
Bidens sp.	T			
Unidentified Material	4.1	5		
TOTAL VEGETABLE	56.6	62	5.8	78
Animal Food				
Snails				
Goniobasis sp.	33.8	37	0.6	8
Planorbis sp.			T	
Physa sp.	1.1	1		
Amnicola sp.	T			
Unidentified Pelecopoda	T			
Unidentified Gastropoda	0.1	0		
Beetle				
Coleoptera	0.2	0	T	
Unidentified Insect			1.0	14
TOTAL ANIMAL	35.2	38	1.6	22
TOTAL FOOD	91.8	100	7.4	100

and gravel made up almost equal amounts of the total gizzard contents, but the diving ducks contained four-fifths gravel and only one-fifth food.

The average volume of food was 2.8 cc. for the pond ducks and 0.4 cc. for the divers. This discrepancy is felt to be a reflection of the migratory characteristics of the two groups. The diving ducks are generally considered strong, fast migrants, whereas, the pond ducks migrate slower and stop frequently to feed while en route south. Aldrich *et al* (1949) state that the recovery of banded birds indicates that the black duck migration pattern follows a gradual drift southward. Since black ducks have been noted wintering and breeding in the vicinity of Millersburg, some of the study specimens may be considered as local ducks.

Table 2 shows the foods of pond ducks and diving ducks. Nomenclature of food species follows that of Hotchkiss (1936) and Gray's Manual (1908). In spite of the relative scarcity of food found in the specimens it is felt that the table has significance in denoting foods utilized by waterfowl in this locality of Pennsylvania. The two geese examined contained 3.2 cc. of the leaves of fingergrass (*Digitaria ischaemum*) and a trace of *Scirpus americanus* seed. Two ruddy duck gizzards contained only 0.1 cc. of *Scirpus americanus* seed and a trace of *Rubus* sp.

Of these local foods, wild millet, common three-square, witch grass (*Panicum capillare*), smartweeds and snails were taken in some quantity, especially by the black ducks. Snails formed about three-fourths of the gizzard contents of the mallards. It is suggested that those waterfowl which migrate slowly take local foods while en route. Conversely, on the basis of identity of plant species represented in the gizzards and the advanced condition of digestion, it would appear that the diving ducks obtain very little food locally.

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—ROBERT G. WINGARD, *West Va. Cons. Commission, Romney, W. Va.*

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CRIPPLING AS A FACTOR IN GRAY SQUIRREL HUNTING

Much emphasis has been placed on crippling as affecting waterfowl, big game, and certain other species. Little attention has been paid to the importance of crippling in small mammal hunting, although data supplied by ammunition manufacturers indicates that the highest annual expenditure of ammunition is for squirrel and rabbit hunting.

Crippling data for gray squirrels, *Sciurus carolinensis*, should be of interest to game managers, since on managed hunts where removal quotas are set this factor must be considered.

The Wheeler National Wildlife Refuge, located in the Tennessee Valley of north Alabama, includes within its boundaries some 5,000 acres of bottomland hardwood timber. Squirrels increased rapidly on the refuge after its establishment in 1938. To hold this population to a normal healthy level and to prevent

excessive damage to corn and other crops, annual managed hunts, authorized by the Fish and Wildlife Service, have been held beginning in 1944 and continuing through 1950.

Since these hunts have been closely supervised, they furnish a good medium for obtaining crippling data. Checking stations were used for four of the seven hunts. Report forms, attached to permits, were used on the other three. Data so obtained should be fairly representative of squirrel hunting in lowland sections of the Eastern States. Hunt dates have varied. They have begun as early as October 1 and continued as late as December 20. The use of squirrel dogs was allowed during four of these hunts but was not permitted during the other three.

Woods vary from mature hardwood timber with numerous den trees and little or no understory to brushy, badly cut-over tracts. Participants varied from habitual squirrel hunters to city dwellers on their first hunting trip. Weather conditions have also varied markedly. All types of firearms were used, along with varying sizes of shot and types of cartridges. Only gray squirrels have been removed by these hunts, since fox squirrels are rare in this locality.

All squirrels wounded but not included in the bag were considered cripples. This would include, along with those that were wounded and escaped, those shot down in brush or water and not retrieved, and those lodged in tree tops.

Crippling figures can never be entirely correct, since errors in human judgment are involved. However, hunters were assured crippling would not influence chances for future permits and appeared to give this information frankly.

Examination of the refuge files indicates 13,009 gray squirrels have been killed on the seven hunts. Those crippled totaled 1,309. This would give a ratio of approximately one animal crippled to each ten brought to bag. Expressed as a percentage, it would give a crippling figure of 10.06.

While all types of firearms were allowed on the hunts, rifles used were exclusively of the .22 caliber rim-fire type. Short, long, and long-rifle ammunition was used with both hollow point and solid bullets. However, the .22 long-rifle cartridge with solid bullet was most commonly used. An estimated 90 per cent of the hunters used shotguns. All gauges from 12 to 401 were represented, although the 12-bore was most commonly used. Various loads and shot sizes ranging from size 4 to 9 were sometimes used, but the majority of hunters used size 6 shot.

During several of the hunts, data on gauge and shot size and type of rifle ammunition were kept in an effort to correlate this with crippling. Little relation was found and these figures were discarded. However, there was noticeable difference in crippling by rifles as compared with shotguns. Separate information on riflemen and shotgunners was kept during the 1946 and 1947 hunts. Combined information for these two years shows a crippling percentage of 12.51 for the .22 rifles and only 9.45 for the shotguns.

The use of squirrel dogs was permitted during the hunts held from 1944 through 1947. Their use was barred from the 1948 through the 1950 hunts. A comparison of these two periods shows an average crippling percentage of 8.67 during the four hunts when dogs were allowed, and an average crippling percentage of 11.04 for the three hunts without dogs. The obvious conclusion would be that the use of dogs materially reduces crippling losses. However, the validity of these figures is open to question because the dog hunts occurred during World War II and the two years immediately afterward when ammunition was in short supply. Efforts of the hunter to make every shot count may have influenced the degree of crippling far more than the use of dogs.

In considering crippling, it must be remembered that all crippled animals cannot be considered a loss. The percentage of recoveries cannot be computed, but there are certainly some recoveries. Those struck by a single shotgun pellet in the foot or tail give obvious evidence of crippling but probably recover quickly. Those shot at too great a range are often merely stung by pellets or have them imbedded just below the skin. In skinning squirrels, the writers have noted numerous instances where the animals bore shot marks or encysted pellets from the previous season. Even those wounded by rifles may recover, since often merely flesh wounds are involved. One squirrel examined had been shot during a previous season and bore a .22 caliber bullet

imbedded in the shoulder muscles. It had completely recovered from the previous wound without ill effects.—THOMAS L. ATKESON and DAVID C. HULSE, *U. S. and Wildlife Service, Decatur, Ala.*

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NOTES AND NEWS

Facilities for studies in marine biology are now available at the Institute of Marine Science of The University of Texas. Course-work and problems for qualified graduates are offered in ecology and fisheries biology under M. D. Burkenroad and G. Gunter. Living quarters and a research vessel are available. The dock-laboratory on Aransas Pass provides unique opportunities for a variety of investigations. Enquiries should be addressed to the Acting Director, Port Aransas, Texas.

LETTER TO EDITOR

Statistical Laboratory,
Cambridge, England.
2/2/52.

The Editor,
J. Wildlife Management.

Dear Sir,

I have recently been referred to Mr. Lowell Adams' article on capture-recapture sampling in 1951 Journal of Wildlife Management, 15(1): 13.

1. *Estimate of T.* The estimator $m\frac{n}{x}$ is biassed and should be replaced by $m\frac{n+1}{x+1}$ (Bailey, 1951, Biometrika 38, 3.).

2. *Confidence limits of Poisson distribution.* Adams' graphs seem to have been drawn from Ricker's figures. These figures are not always accurate in the last digit and the graph suffers accordingly, e.g. the lower 95% limit for $x = 9$ is in fact 4.12. The correct figures are given in Fisher & Yates' Statistical Tables for Biological, Agricultural and Medical Research, (Table VIII 1), and elsewhere. Of course, the use of a table gives more accurate results than reference to a graph, especially since the binomial limits can then be used, however small the value of $\frac{x}{n}$.

Yours faithfully,
NEIL GILBERT